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A Note on the Inheritance of Short Lower Jaw or Parrot Mouth in Sheep.

*By R. B. Kelley, D.V.Sc.**

In sheep with shortened lower jaws, the incisors oppose the palate instead of the dental pad, and the apposition takes place approximately three-quarters of an inch posterior to the normal position as shown in Plate 1. The inheritance of the condition has been studied in a small group of sheep.

A Merino ram, M_3, was depastured with an experimental group of Merino ewes, and with his progeny from them. While running with the flock he mated with his own daughters, bred within the group, and later with his own grand-daughters.

By January, 1942, twelve of his daughters had borne progeny to him. One had borne three lambs, four had borne two, and seven had each borne one lamb. In 1940 the original ram (M_3) was withdrawn temporarily and was replaced by one of his sons. This son, A118, left one ram lamb out of a ewe by his father.

Typical pedigrees from some of these matings are shown in Fig. 1, (*a*) and (*b*).

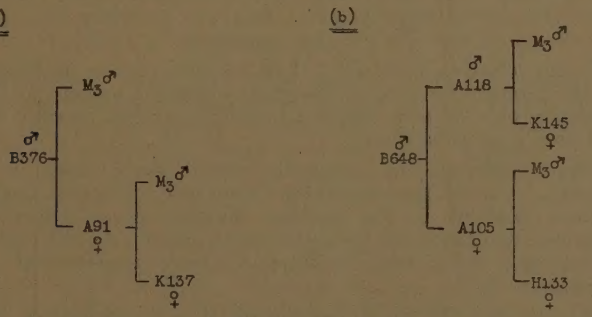

Fig. 1.—Pedigrees of Two Cases of Short Lower Jaw.

The pedigree outlined in Fig. 1 (*a*) shows A91 as a daughter of M_3, and the mating between father and daughter with the product, B376.

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The length of the lower jaw of this lamb, B376, was so abnormal that it was impossible to rear him.

The pedigree outlined in Fig. 1 (*b*) shows the product, B648, of the mating of a son and a daughter of M_3. This lamb also showed the abnormal condition of the jaw. However, he has been stall fed throughout, with good prospects of rearing him for further experimental matings. The ewe A105 bore three other lambs to M_3—all were normal. The ewe A91 has borne only the lamb B376.

There were two kinds of ewes in the original group, those with the prefix letter H, and those with the prefix letter K. The history of these sheep is well known. Until it was made on this Field Station, there had been no admixture of their "blood" lines for at least upwards of 80 years.

The shortened lower jaw is a recessive condition discovered by the inbreeding. Further, because the only relationship common to the ram lambs B376 and B648 is that to M_3, unless it is very widespread, the condition must have been inherited through him. It is reported in its earliest stages of investigation because the lessons to be learnt from it are important.

They are of interest to sheep breeders who are progeny-testing sires, and are of particular interest to those who, by artificial insemination, are extensively using sires appraised only by the relative excellence of progeny from ewes not closely related to the rams.

The ram M_3, when mated with ewes other than his own daughters, left 78 lambs, all of which had normal jaws. His excellence as a sire would have been appraised from an examination of the wool and other characters of these lambs, and it would have governed his future use. If, as a stud ram, he were appraised highly, probably he would have been used extensively by hand service or by artificial insemination.

It was not until he was mated with twelve of his own daughters that the condition was discovered, and then it only occurred once among eighteen lambs from them. It is emphasized that M_3 begat three normal lambs from the daughter A105, which later bore the abnormal B648. Relatively large numbers thus are necessary for appropriate sire x daughter tests for recessive conditions in the sire.

If the defective lamb, B376, had not occurred, or if its appearance had been excused for a ram with highly appraised progeny as happening so seldom, only once in eighteen possibilities, then possibly M_3 would have been used extensively.

The condition then, potentially, would have become widespread, although it would not have been discovered until the progeny were line-bred as shown in Fig. 1 (*b*). Further, if, as is most common, incomplete pedigrees had been kept on the ewes' side, the condition not only would have been widespread, but incapable of adequate explanation.

Examination of highly appraised sires by relatively numerous sire x daughter matings is essential before such sires can be used extensively with safety.

Studies on the Chemical Composition of Pods and Seeds of Certain Species of *Medicago*, with a Note on the Apparent Digestibility of Cluster Clover (*Trifolium glomeratum* L.) Seed.

By M. C. Franklin, M.Sc., Ph.D. (Cantab.), A.I.C. and R. F. Powning.†*

Summary.

(1) There are wide chemical and physical differences between the burrs and seeds of the several species of *Medicago* examined in this study. For example, the crude protein content of the whole burrs ranged for the several species from 13·11 per cent. to 24·75 per cent., and for seeds from 27·65 per cent. to 49·96 per cent. The seeds may be regarded as a protein-rich concentrate and, to a lesser extent, this is true also of some of the burrs. The data emphasize the value of the burrs as a natural fodder reserve.

(2) In common with other grains the seeds of *Medicago* species are relatively poor in lime and rich in phosphate. However, the hull portion of the whole burrs is rich in lime and, in the aggregate, sheep which are consuming moderate quantities of the burrs should require no additional supplement of lime.

(3) There is considerable difference between the seed size of the different species of *Medicago*. Thus samples of *M. laciniata* contained from 454 to 526 seeds per gramme, whereas samples of *M. scutellata* contained from 48 to 58 per gramme. This difference may be of importance in considering the ability of sheep to digest seeds from the different species.

(4) Of particular interest is the fact that among the species of *Medicago* investigated in this work the seeds of all except *M. orbicularis*, and the pods of all except *M. scutellata* were richer in crude protein than *M. hispida denticulata* which is the commonest and most widespread annual medic.

(5) Sheep fed on a mixture of equal portions of lucerne chaff and cluster clover (*T. glomeratum*) seed digested the total dry matter 63 per cent. more efficiently when the clover seeds were ground. Grinding raised the apparent digestion coefficient of the crude protein of the cluster clover seed from 39·7 per cent to 83·9 per cent., an increase of 125 per cent.

I. Introduction.

In those areas of Australia where *Medicago* species flourish, the large accumulation of burrs or pods provides a valuable fodder reserve for sheep. However, little detailed information has been collected on the chemical composition of these pods and seeds. Shapter (1935) published analyses of the seeds of a species referred to as *Medicago denticulata* and, among other data, recorded a crude protein content of 22·88 per cent. Frequent stress has been laid on the need of stock for protein. Further, Davies (1941) stated that the limitation to stock raising in Queensland lies in the low nutritive value of the pastures over long periods of the year. He urged that the search for suitable legumes be intensified since success would transform the pasture outlook of coastal Queensland and New South Wales from one of doubtful stability to one of sound practical development.

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It is equally true that an increase in legume production in certain inland districts should assist in raising the nutritional plane of stock in these areas. Information on the chemical composition of foodstuffs grown there should, therefore, be of material assistance in formulating future policy in respect to the introduction of new pasture plant species or the improvement and encouragement of existing species.

2. Experimental Material

Towards the end of 1940 a sample of mixed burrs of *M. laciniata* (Cut-leaf Medic), *M. minima* (Small Burr Medic), and *M. hispida denticulata* (Common Burr Medic) was collected near Gilgandra, New South Wales.

The sample was considered to be representative of much of the burr available to stock on the central and northern plains of New South Wales during the severe drought of 1940.

Subsequently a range of pod (or "burr") material of seven species of *Medicago* was generously supplied from Canberra by the Division of Plant Industry of the Council. Analyses of these samples are included in this article. Samples of subterranean clover (*Trifolium subterraneum*) were included for comparison.

The identification and origin of the samples analysed are as follows:—

M.O.—51 (*M. orbicularis*) received originally from Lawes, Queensland.

M.O.—64 (*M. orbicularis*) commercial sample grown at Werris Creek, New South Wales, 1940-41.

M.Sc.—11 (*M. scutellata*) received originally from Wagin, New South Wales.

M.Sc.—14 (*M. scutellata*) received originally from Lawes, Queensland.

M.Tr.—89 (*M. truncatula*) received originally from Forbes, New South Wales.

M.Tr.—134 (*M. truncatula*) received originally from Roseworthy, South Australia.

M.Tr.—137 (*M. truncatula*) received originally from Murray Bridge, South Australia.

M.A.—17 (*M. arabica*) received originally from Dirnaseer, New South Wales.

M.H.D.—65 (*M. hispida denticulata*) received originally from Glen Osmond, South Australia.

M.H.D.—225 (*M. hispida denticulata*) received originally from the United States of America.

M.H.R.—X. (*M. hispida reticulata*) received originally from the United States of America.

M.Lc.—43 (*M. laciniata*) received originally from Trangie, New South Wales.

T.S.—553 (*Trifolium subterraneum*), Dwalganup variety.

With the exception of M.O.—64 all the samples were grown in 1940 at Canberra under the same conditions.

One set of samples was collected at maturity, and a duplicate collection was made some ten weeks later, after approximately 14 inches of rain had fallen. One sample of M.Sc.—14 had been left in the field

for more than a year after maturity. It was considered that this might provide useful information on the influence of ageing in the field and on leaching losses. Some of the samples carried much soil, particularly those collected after rain. Most of the soil was removed by mechanical agitation of the contaminated samples in a fine mesh sieve, but it was not possible to remove it all without damaging the hull excessively. A reasonable measure of soil contamination can be obtained from the total ash analyses given in Table 2.

3. Experimental Results.

In addition to chemical analyses of the whole "burr" and samples of seeds, data were collected on the size of the burrs, size of seeds, and relative amounts of seed and hull making up the total burr. These data are of importance in nutritional considerations. For example, if seeds are small and have a hard seed coat the animal may be unable

TABLE 1.—PHYSICAL CHARACTERS OF MATURE PODS (OR "BURRS") OF VARIOUS SPECIES OF ANNUAL LEGUMES.

Species of *Medicago* and *Trifolium*.	Progeny.	Date Collected.	Weight of 1,000 pods.	Number of Seeds in 1,000 pods.	Range of Seeds per pod.	Per cent. by Weight of whole burr.	
						Seeds.	Hull.
			g.				
M. orbicularis .. Button Medic ..	M.O. 51	27.1.41	123·9	13,780	10–19	49·0	51·0
	M.O. 64	1940–41	95·3	13,200	7–18	50·6	49·4
M. scutellata .. Snail Medic ..	M.Sc. 11	Nov. 1940	241·5	4,600	3–6	32·5	67·5
	M.Sc. 11	22.1.41	269·4	5,070	4–6	33·5	66·5
	M.Sc. 14	*	240·1	3,570	2–5	27·7	72·3
	M.Sc. 14	Nov. 1940	309·2	4,870	4–6	32·8	67·2
	M.Sc. 14	24.1.41	268·0	4,630	3–6	35·7	64·3
M. truncatula .. Barrel Medic ..	M.Tr. 89	27.1.41	151·3	10,300	8–13	26·9	73·1
	M.Tr. 134	Nov. 1940	142·2	7,230	5–9	25·6	74·4
	M.Tr. 134	28.1.41	150·0	7,830	6–10	25·9	74·1
	M.Tr. 137	Nov. 1940	116·9	7,030	4–9	26·4	73·6
	M.Tr. 137	28.1.41	116·3	7,300	4–9	27·8	72·2
M. arabica .. Spotted Medic	M.A. 17	3.2.41	40·0	5,030	4–7	33·9	66·1
M. hispida var. *denticulata* Common Burr Medic	M.H.D. 65	Nov. 1940	77·1	6,270	4–9	30·0	70·0
	M.H.D. 65	3.2.41	75·0	7,430	4–10	35·0	65·0
	M.H.D. 225	Nov. 1940	54·9	5,330	3–8	32·8	67·2
	M.H.D. 225	3.2.41	59·9	6,530	4–8	38·8	61·2
M. hispida var. *reticulata* Spineless large-podded Medic	M.H.R. ..	25.1.41	111·1	7,600	4–10	31·4	68·6
M. laciniata .. Cut-leaf Medic ..	M.Lc. 43	Nov. 1940	58·3	9,000	7–12	34·4	65·6
	M.Lc. 43	22.1.41	44·3	9,100	7–11	38·5	61·5
T. subterraneum .. Subterranean Clover	T.S. 553	Dec. 1940	104·0	3,480	1–6	37·8	62·2
	T.S. 553	25.1.41	101·2	3,470	2–6	36·8	63·2

* Pods left in field from December, 1939, to January, 1941.

to digest them efficiently. This point is well illustrated in data on the digestibility of cluster clover seed which are included in this article.

The data in Table 1 illustrate the following points with respect to the progenies listed:—

(*a*) Large differences exist in pod size and weight between different species. For example, pods of *M. scutellata* tend to be from 4 to 5 times heavier than those of *M. hispida denticulata.*

(*b*) The number of seeds per pod varies considerably.

(*c*) The relative weight of seeds to hull is fairly constant within species but differs between species, e.g., with *M. orbicularis* approximately half the weight of the pod is made up of seed, whereas in *M. truncatula* samples, the seeds account for only about a quarter of the weight of the pod.

(*d*) Pods left in the field for a long period (see M.Sc.—14) suffered an appreciable loss in seeds with a proportionate drop in percentage weight of seed to hull.

In Table 2 data obtained by Shapter (1935) for *M. denticulata* are included for comparison.

The seed was then hand-picked from further samples of burrs, and freed completely from hull and from particles of soil. Analyses of the seeds are given in Table 3.

Data in Tables 1, 2, and 3 deal only with different strains of the various species. Under field conditions a mixture of species will usually be present. The following data were obtained from a sample of burrs obtained in 1940 from near Gilgandra, New South Wales. It was a mixture of burrs from *M. laciniata, M. minima,* and *M. denticulata,* and was similar to much of the burr to be found in New South Wales.

In addition to determining the crude protein content, a mechanical analysis into true seeds and hull was also made. In the mechanical analysis the seeds were separated from 324 burrs. The number of seeds per burr ranged from 0 to 10, with an average for the complete sample of approximately 4 seeds to each burr. The seeds totalled 34·2 per cent. of the total weight of the burrs, and the hull fraction 65·8 per cent. Chemical analysis was as follows:—

Seeds	45·65 per cent. crude protein.
Hull	10·42 per cent. crude protein.
Complete burrs	21·75 per cent. crude protein.

Although some loss of seeds had obviously occurred in this sample, as revealed by the fact that seeds were entirely absent from some apparently mature burrs, the crude protein content of seeds and complete burrs was comparable with that of the individual species listed in Tables 2 and 3. It would seem that material which has lain in the field for periods of one or two years under the conditions prevailing during 1939-40 did not suffer a serious change in relative proportions of crude protein and other constituents. This is supported by data in Table 2. For example a comparison of samples collected during November, 1940, with those collected ten weeks later shows that soil contamination was marked with the samples collected at the later date, but otherwise these were little affected. Even the samples of *M. scutellata,* which had lain in the field for approximately fourteen

TABLE 2.—CHEMICAL COMPOSITION OF PODS INCLUDING SEEDS (ANALYSES EXPRESSED ON 100 PER CENT. DRY MATTER BASIS).

Species.*	Crude protein.	Ether extract.	N-free extract plus crude fibre.	Organic matter.	Total ash.	Lime CaO.	Phosphate P_2O_5.	Nitrogen N.
M. orbicularis—	%	%	%	%	%	%	%	%
51/41	15·73	2·36	70·63	88·72	11·28	0·95	0·45	2·52
64/41	18·35	2·32	72·65	93·32	6·68	1·13	0·85	2·94
M. scutellata—								
11/40	13·67	3·41	76·35	93·43	6·57	1·11	0·33	2·19
11/41	13·11	3·36	54·61	72·08	27·92	0·79	0·38	2·10
14/39–41	14·31	3·27	53·26	71·84	28·16	1·06	0·46	2·29
14/40	15·24	3·61	66·58	85·43	14·57	0·87	0·49	2·44
14/41	17·41	4·33	65·28	87·02	12·98	1·05	0·73	2·79
M. truncatula—								
89/41	18·89	3·59	69·38	91·86	8·14	1·16	0.35	3·02
134/40	17·05	4·67	72·92	94·64	5·36	1·32	0·26	2·73
134/41	17·70	4·03	71·04	92·77	7·23	1·50	0·29	2·83
137/40	18·44	4·38	72·32	95·14	4·86	1·33	0·36	2·95
137/41	18·33	4·17	69·39	91·89	8·11	1·36	0·38	2·93
M. arabica—								
17/41	19·07	5·01	54·51	78·59	21·41	2·78	0·57	3·05
M. hispida var. *denticulata*—								
65/40	16·63	2·64	73·90	93·17	6·83	1·12	0·53	2·66
65/41	13·39	2·73	58·68	74·80	25·20	0·81	0·52	2·14
225/40	16·46	2·98	73·94	93·48	6·52	1·18	0·51	2·63
225/41	14·47	3·08	59·19	77·74	22·26	1·01	0·56	2·32
M. hispida var. *reticulata*—								
M.H.R./41 ..	15·55	3·17	66·14	84·86	15·14	1·30	0·36	2·49
M. laciniata—								
43/40	24·75	3·75	64·64	93·14	6·86	2·50	0·40	3·96
43/41	22·86	3·35	42·59	68·81	31·19	1·86	0·39	3·66
Trifolium subterraneum—								
553/40	22·55	6·72	60·70	89·97	10·03	0·61	0·76	3·61
553/41	18·21	5·62	52·32	76·15	23·85	0·61	0·60	2·91
M. denticulata—								
Shapter (1935) ..	22·88	3·09	69·33	95·30	4·70	..	0·61	3·66

* Reference to Table 1 will provide the key, in respect to species, progeny number, and date of collection of samples, to numbers listed in this column.

months, differed very little in chemical composition from more recently harvested samples. A reasonably accurate measure of the degree of soil contamination can be obtained from a study of the total ash figures. For example, with *M. hispida denticulata* two samples collected in November, 1940, contained 6·83 and 6·52 per cent. of total ash; further samples collected in February, 1941, contained 25·20 and 22·26 per cent. of total ash, respectively.

TABLE 3.—CHEMICAL COMPOSITION OF SEEDS (ANALYSES EXPRESSED ON 100 PER CENT. DRY MATTER BASIS).

Species.*	Crude protein.	Ether extract.	Crude fibre.	N-free extract.	Organic matter.	Total ash.	Lime CaO.	Phosphate P_2O_5.	Nitrogen N.
M. orbicularis—	%	%	%	%	%	%	%	%	%
51/41	27·65	..	..	..	..	..	0·36	0·80	4·42
64/41	31·55	4·62	14·10	45·08	93·35	4·65	0·31	1·42	5·05
M. scutellata—									
11/40	36·96	..	..	..	..	..	0·24	1·06	5·91
11/41	39·93	12·40	9·77	34·48	96·58	3·42	0·22	1·21	6·39
14/39–41 ..	41·20	..	..	..	..	..	0·18	1·47	6·59
14/40	41·26	..	..	..	..	..	0·17	1·21	6·60
14/41	40·57	11·58	10·42	33·26	95·83	4·17	0·19	1·77	6·49
M. truncatula—									
89/41	45·45	..	10·76	..	..	..	..	1·30	7·27
134/40	47·69	..	..	..	..	..	0·26	0·95	7·63
134/41	42·27	15·59	10·29	25·8	94·95	5·05	0·25	0·96	6·92
137/40	46·79	..	..	..	..	..	0·24	1·19	7·49
137/41	46·26	..	..	..	..	..	0·24	1·24	7·40
M. hispida var. *denticulata*—									
65/40	36·08	..	..	..	..	..	0·37	1·32	5·77
65/41	32·59	7·31	11·27	43·7	94·87	5·13	0·32	1·47	5·21
225/40	36·38	..	..	..	..	..	0·36	1·31	5·82
225/41	33·75	..	..	..	..	..	0·33	1·38	5·40
M. hispida var. *reticulata*—									
M.H.R./41 ..	39·48	9·72	12·00	32·48	95·37	3·63	0·37	0·98	6·32
M. laciniata—									
43/40	49·96	..	..	..	..	..	0·36	0·99	7·99
43/41	48·85	..	..	..	..	..	0·33	1·06	7·82
T. subterraneum—									
553/40	41·59	..	..	..	..	..	0·24	1·76	6·66
553/41	38·73	..	..	..	..	..	0·25	1·67	6·20
T. glomeratum—									
Commercial sample	34·74	..	..	..	96·38	3·62	0·34	1·24	5·56
T. subterraneum—									
Shapter (1935) ..	39·63	15·16	9·01	31·63	95·43	4·57	..	1·65	6·34

* Reference to Table 1 will provide the key, in respect to species, progeny number, and date of collection of samples, to numbers listed in this column.

4. Metabolism Studies on Cluster Clover (*Trifolium glomeratum*) Seed.

Data collected in a trial, wherein cluster clover seeds were fed to sheep, are of interest concerning the effect of seed-size on digestibility. The results obtained give independent support to the suggestion that seed-size should not be overlooked when considering the establishment of *Medicago* species as forage plants.

Four merino wethers were fed, in metabolism cages, on a mixture of equal parts of lucerne hay and of cluster clover seed. Preliminary observations on faecal samples suggested that much of the cluster clover seed was passed through the alimentary canal unchanged. Careful separation of the seeds from the faeces confirmed this.

(*a*) *Experimental procedure of metabolism trial.*

Four Merino wethers were placed in metabolism cages. Two were fed on a mixture containing equal parts (by weight) of lucerne chaff and uncrushed cluster clover seed, the remaining two received equal parts of lucerne chaff and crushed clover seed, 400 grammes of the respective mixtures being fed to each animal twice daily. A pre-experimental period of eight days was followed by the experimental period of nine days during which faecal and urine samples were collected for analysis.

Wether No. X.164, on the lucerne and crushed clover seed ration, did not take it readily, and had to be excluded from the digestion trial.

(*b*) *Summary of metabolism trial data.*

Apparent digestion coefficients were determined for the dry matter, and the crude protein in the mixed lucerne chaff and cluster clover seed ration. Other data collected included weight of whole clover seed excreted in the faeces of those animals receiving uncrushed seed, calculation of the digestibility of the crude protein of the seed alone, and changes in body-weight of individual animals. These results are summarized in Table 4.

Wethers No. X.158 and No. X.168, for which the seed was not crushed, digested 46·3 and 50·2 per cent., respectively, of the dry matter in their rations—an average of 48·25 per cent.—and 44·6 and 49·2 per cent, respectively, of the crude protein—an average of 46·9 per cent. Wether No. X.163, which received the same quantities of feed but for which the clover seed had been crushed, digested 76·6 per cent. of the dry matter and 83·8 per cent. of the crude protein in the ration.

TABLE 4.—RESULTS OF A FEEDING TRIAL WITH CRUSHED AND UNCRUSHED CLUSTER CLOVER SEED FED AT THE RATE OF 400 g. OF SEED PER DAY ALONG WITH AN EQUAL QUANTITY OF LUCERNE CHAFF.

Group.	Wether Number.	Body-weight change in 18 days.	Apparent digestion coefficients of—			Recovery of whole undigested seeds from faeces.
			Dry matter.	Crude protein of mixture.	(Calculated) Crude protein of seed.	
		lb.	%	%	%	%
Crushed seed	X 163	+ 1	76·6	83·8	89·3	..
	X 164*	− 1				
Uncrushed seed	X 158	−10·5	46·3	44·6		57·3
	X 168	− 8	50·2	49·2		56·0
			Average 48·25	Average 46·9	39·7	

* Consumed only approximately three-quarters of daily ration.

As would be expected, retention of nitrogen by the different experimental animals showed just as striking differences. Nos. X.158 and X.168, receiving uncrushed clover seed, stored an average of 2·1 g. and 4·2 g. of nitrogen per day, whereas No. X.163, receiving the crushed clover seed, stored an average of 8·4 g. of nitrogen per day.

Data included in Table 4 on the weight of whole clover seed excreted in the faeces of wethers No. X.158 and No. X.168 show that 57·3 per cent. and 56·0 per cent., respectively, of the undigested seeds were recovered from the faeces of these two animals.

Also included in Table 4 are data for the calculated digestion coefficient of the clover seed alone. Wood and Woodman (1939) state that the crude protein of good quality lucerne hay has an apparent digestion coefficient of 75 per cent. Applying this figure in the present experiment it can be calculated that the apparent digestion coefficient of the crude protein of the uncrushed cluster clover seed was 39·7 per cent., and of the crushed seeds 89·3 per cent.

Live weight changes shown in Table 4 but obtained over such a short period on a small group of animals may be misleading, but the striking differences were supported by the data from the metabolism trial. During the 18-day period, wethers No. X.158 and No. X.168, each consuming daily 400 g. of lucerne chaff and 400 g. of *uncrushed* clover seed, lost 10½ lb., and 8 lb. body weight, respectively. Wether No. X.163, receiving 400 g. of lucerne chaff and 400 g. of *crushed* clover seed, gained 1 lb. in weight over the same period, whereas wether No. X.164, which ate approximately 300 g. each of the lucerne chaff and of the *crushed* clover seed per day, lost only 1 lb.

5. Discussion.

Both the quality and quantity of standing pasture rapidly falls off under dry conditions. For example, Davies, Scott, and Kennedy (1938) have estimated that the nutritive ratio of Mitchell grass pasture may, under certain conditions, range from 1:7 to 1:33. Widely accepted data indicate that the nutritive ratio of the diet of sheep should be approximately 1:10 for maintenance and about 1:4 or 1:5 for production. The analyses recorded in Table 2 indicate that the pods of the various *Medicago* species should approximate productive nutritive ratios, whilst from the data given in Table 3 the nutritive ratios of the seeds of many of the varieties lie between 1:1 and 1:2. Large differences, which are obvious from a study of the data given in Tables 2 and 3, exist between the different species. For example, the two samples of seed from the *M. orbicularis* progenies contained 27·65 per cent. and 31·55 per cent. of crude protein, whereas seed from the two progenies of *M. laciniata* contained 48·85 per cent. and 49·96 per cent. of crude protein.

In common with other grains the seeds of the *Medicago* and *Trifolium* species investigated were found to be poor in calcium and rich in phosphorus (see Table 3). However, consideration of the data in Table 2 shows that the hulls of *Medicago* and *Trifolium* species are rich in lime, so rich that whereas, for example, the seeds of *M. scutellata* (M.Sc.—11, November, 1940), have a CaO/P_2O_5 ratio of 1:4·4 the whole burrs of this species have a ratio of 3·4:1. Similarly, the seeds of *T. subterraneum* (T.S.—553, December, 1940) have a CaO/P_2O_5

ratio of 1:7·3 whereas the whole burrs have a ratio of 1:1·2. Consumption of a reasonable quantity of burrs should therefore provide sufficient lime for all normal requirements of sheep.

Digestion of the true seed ingested while still in the burrs will probably be more efficient than that of seeds freed from the hull. Our data suggest, however, that seed size, other things being equal, should also be considered. The results obtained in this experiment showed that the sheep is unable to digest efficiently such small seeds as those of cluster clover when they are fed in the unground state as part of the ration. Changes in body weight of the experimental animals, digestion coefficients, nitrogen balance studies, and the large quantity of undigested seeds recovered from the faeces, all support this view.

A comparison of seed size is therefore of importance, and the following figures have been calculated from data in Table 1.

Table 5.—Seed Weight of Certain Species of Annual Legumes.

Species.	Weight of 1,000 Seeds.	Number of seeds per gramme.
	g.	
M. orbicularis	3·7– 4·4	227–270
M. scutellata	17·1–20·8	48–58
M. truncatula	4·0– 5·0	200–250
M. arabica	2·7	370
M. hispida denticulata	3·4– 3·7	270–294
M. hispida reticulata	4·6	217
M. laciniata	1·9– 2·2	454–526
Mixed sample of *M. laciniata*, *M. minima*, and *M. denticulata* from Gilgandra, New South Wales ..	1·3	769
T. subterraneum	10·7–11·3	88–93
T. glomeratum	0·4	2,500

Table 5 shows that seeds of all the *Medicago* species considered here are larger than those of cluster clover. The smallest of the *Medicago* seeds were derived from the mixed sample collected near Gilgandra, New South Wales, due to the presence of a large percentage of *M. minima* in this mixed sample.

Morrison (1936) believes that there is generally no advantage in grinding grain or other seeds for sheep unless they are unusually small or hard. It is obvious from their appearance, and from the data obtained in this trial, that cluster clover seed can be included in this class of small or hard seed. In the *Medicago* species the seeds are held firmly within the burrs, and possibly because of this are effectively crushed by the sheep with its cud. The satisfactory condition of sheep when *Medicago* burrs appear to form the bulk of the ration suggests that the animals are utilizing their food efficiently. Further experiments to study this are desirable.

6. Acknowledgments.

It is a pleasure to acknowledge the assistance of Mr. F. W. Hely, B.Sc.Agr., of the Genetics Section, Division of Plant Industry, Canberra, who selected the species used, provided the material from the Section's collection, and gave helpful suggestions in the compilation of the botanical data presented in this paper.

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The Treatment of Outbreaks of Haemonchosis.

By H. McL. Gordon, B.V.Sc., I. W. Montgomery, B.V.Sc.,† and L. K. Whitten, B.V.Sc.‡*

Summary.

1. Treatment of haemonchosis under outbreak conditions was studied, and the special problems encountered are discussed.

2. The great value of phenothiazine in controlling outbreaks was shown, and the shortcomings of carbon tetrachloride and copper sulphate-nicotine mixture were demonstrated.

3. Successful control of haemonchosis under outbreak conditions requires repeated treatments. Anthelmintics which depend for their efficiency upon copper sulphate bringing about direct passage into the abomasum should be alternated with carbon tetrachloride.§

1. Introduction.

During the summer of 1940-41 severe outbreaks of haemonchosis occurred throughout the north and north-west of New South Wales. Repeated rains had resulted in a prolonged period favourable for such outbreaks. The opportunity was therefore taken to determine the effects of anthelmintic treatment on a rapidly increasing population of *H. contortus*, including many immature forms. General observations in the district showed that in many instances the drugs usually employed (copper sulphate, copper sulphate-nicotine mixture, arsenic, carbon tetrachloride) failed to control outbreaks of haemonchosis satisfactorily. Failure to repeat treatment at short intervals appeared to be the commonest cause of the apparent inefficiency of the drugs used.

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§ This article was written when ample supplies of carbon tetrachloride were available.

Two reasons for the failure of certain anthelmintic drugs under outbreak conditions have emerged from recent experiments: (*a*) The commonly used anthelmintics are relatively ineffective against immature *H. contortus* (Gordon, 1939) and hence treatments should be repeated at short intervals (about ten days) during periods when reinfestation is in progress; this is very seldom done. (*b*) The repeated failure of individual sheep to respond to copper sulphate-nicotine mixture (Gordon and Whitten, 1941), and this probably applies also to copper sulphate alone or in mixtures with sodium arsenite, indicated that under conditions which favour heavy reinfestation from the pasture other drugs, which are efficient even when swallowed into the rumen, must be used if mortalities and continued contamination of pastures are to be avoided. Carbon tetrachloride and phenothiazine are the only anthelmintics known to have this property.

In the experiments here described, three anthelmintics were used. Phenothiazine was included because it is highly efficient against immature *H. contortus* (Gordon, 1940) and is efficient even when swallowed into the rumen (Gordon and Whitten, 1939). Carbon tetrachloride was included because it is relatively ineffective against immature *H. contortus,* but is usually highly effective against mature *H. contortus* even when injected into the rumen (Gordon, unpublished). Copper sulphate-nicotine mixture was included because it is moderately efficient against immature *H. contortus,* being better than carbon tetrachloride in this respect, but is only efficient against mature *H. contortus* when swallowed into the abomasum (Gordon, unpublished).

2. The Experiment.

About 100 sheep were used. They were thirteen months old, and were individually numbered with ear tags. They grazed the same pasture throughout the trial in order to provide optimal conditions for reinfestation.

The sheep had acquired moderate to heavy infestations with *H. contortus* by the beginning of November, 1940. Faecal samples were collected at approximately weekly intervals from 13th November to 13th March for egg counts and for the differential counting of larvae in cultures. The experimental treatments were carried out on 28th November and 14th January. Extra treatments were carried out on individuals and at times discussed later in this paper.

The sheep were divided into four groups having comparable degrees of infestation. Three groups received anthelmintic treatment on 28th November, and one group was left untreated as a control. Reinfestation occurred and after the faecal examinations on 10th January the sheep were re-allotted to four groups and treated on 14th January. Reinfestation continued, and after inspecting the sheep on 28th January, several which showed marked anaemia were treated with copper sulphate-nicotine mixture (sheep marked T in Fig. 2).

The dose rates used were: Phenothiazine, 15 grammes suspended in water; carbon tetrachloride, 2 ml. mixed with 3 ml. liquid paraffin; copper sulphate-nicotine mixture, 25 ml. containing 4 per cent. of each of the two drugs.

FIG. 1.

(NOTE. On 10.1.41 the sheep were re-allotted to four groups. Egg counts on 2.1.41 are recorded twice, in Fig. 1 for the groups used for the first treatment, and in Fig. 2 for the groups as re-allotted for the second treatment.)

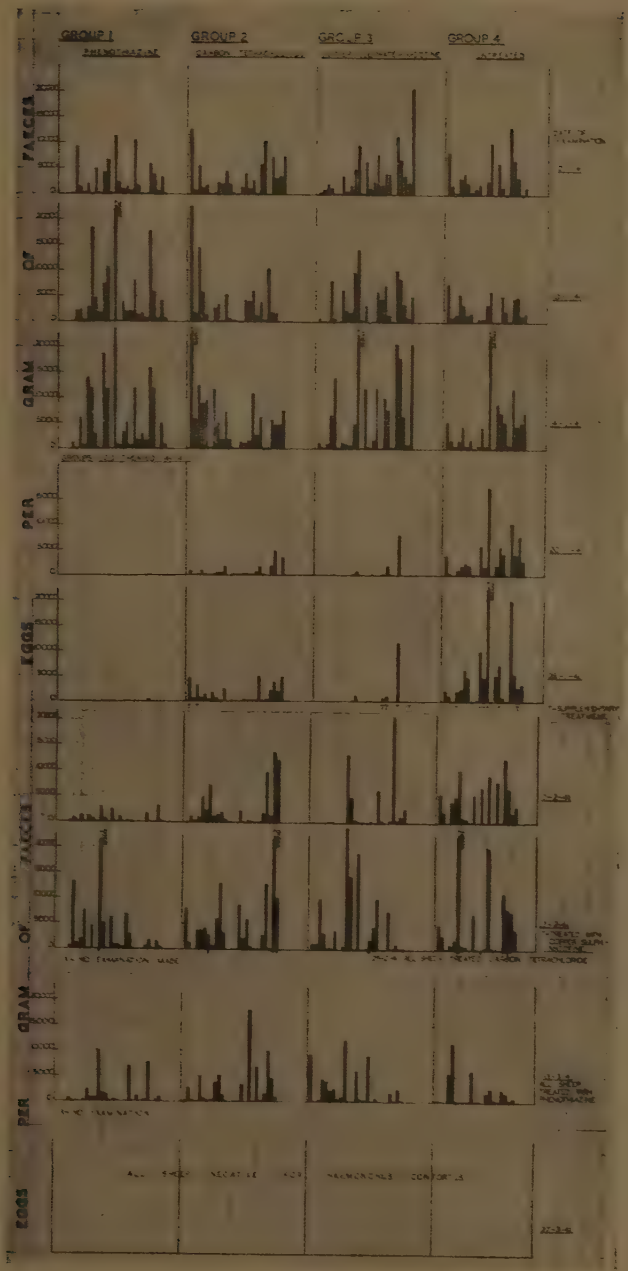
GROUP 1
GROUP 2
GROUP 3
GROUP 4
PARCEL
GRAM
PER
EGGS
PARCEL
GRAM
PER
EGGS

Fig. 2.

3. Results.

Results are shown in Figs. 1 and 2, which record the number of *H. contortus* eggs per gramme of faeces of the sheep in the four groups. On each date the egg count for any particular individual is recorded in a position corresponding with that for the same sheep at preceding and succeeding dates. The changes in egg count for any individual may be followed by using a ruler placed parallel with the column representing the count. On some occasions it was not possible to obtain faecal samples from all the sheep. In the figures this is indicated by "x" in the position where the egg count would have been recorded.

Fig. 1 shows the changes in egg counts following the first treatment on 28th November. It was unfortunate that on 23rd December faecal samples could not be obtained from a large proportion of the sheep—one in group 1, four in group 2, six in group 3, and eleven in group 4. Had these records been completed it is probable that differences between groups would have been more strikingly shown. It will be observed that phenothiazine was highly effective, removing all *H. contortus* from 24 of the 27 sheep and leaving very small residual infections in the other three. Carbon tetrachloride was much less effective, although it considerably reduced the egg counts in all the sheep treated. Copper sulphate-nicotine sulphate mixture was similar in efficiency to carbon tetrachloride except that it failed completely in three of the 24 treated sheep. In these three sheep the mixture probably entered the rumen.

During the period from 5th December to 23rd December a number of sheep in the control group showed the phenomenon known as "self-cure" and egg counts decreased. "Self-cure" however was not followed by resistance to reinfestation, for by 2nd January egg counts in this group were approaching the previous high levels. No doubt "self-cure" also occurred in some of the sheep in groups 1, 2, and 3, and complicated the determination of anthelmintic efficiency. On 2nd January there were no very striking differences between the groups, and it was clear that reinfestation had been rapid. Under conditions of normal sheep-husbandry, treatment should have been repeated on, or before, 23rd December, that is, less than one month after the initial treatment.

The results of the second treatment on 14th January are shown in Fig. 2. Phenothiazine was again highly efficient. The copper sulphate-nicotine mixture failed in only one sheep. Reinfestation proceeded rapidly during the following weeks, and was not complicated by the occurrence of "self-cure." On 28th January many of the sheep in groups 2, 3, and 4 showed marked anaemia, and some were treated with copper sulphate-nicotine mixture (two in group 2, four in group 3, and six in group 4). Despite this supplementary treatment egg counts increased, and on 7th February (Fig. 2) were approaching pre-treatment levels in groups 2 and 3. On 17th February, just over one month after treatment, the outbreak was again in progress.

In this section of the experiment phenothiazine was markedly superior to the other anthelmintics. The prolonged periods of low egg counts following its use are of great importance in the control of outbreaks of haemonchosis.

On 17th February some sheep were showing severe anaemia and received supplementary treatment with copper sulphate-nicotine

mixture. In group 1, one; in group 2, three; in group 3, one; and in group 4, four sheep were so treated.

On 25th February, 42 days after the experimental treatments, the colour of the skin and the conjunctival membranes of the sheep were carefully examined and the approximate degree of anaemia was recorded. In group 1 there were six, in group 2 eight, in group 3 eleven, and in group 4 there were nine sheep showing marked anaemia. All sheep were treated on this date with carbon tetrachloride.

On 13th March faecal examination showed that there were still some heavily infested sheep present (Fig. 2), and on this date all sheep were treated with phenothiazine. Faecal examinations on 27th March showed complete absence of *H. contortus*.

4. Discussion.

The observations here recorded illustrate the succession of changes in the worm burden of sheep during an outbreak of haemonchosis. The efficiency of three anthelmintics was examined under these conditions and the results aid in explaining the failure of anthelmintic treatment observed in outbreaks during previous years. The remarkable efficiency of phenothiazine under outbreak conditions is an extremely valuable addition to its many other virtues. It appears that by using this drug an outbreak of haemonchosis might be controlled with a single treatment if sheep were moved to a spelled paddock, or with two treatments if not moved from a contaminated pasture.

The experiment here described did not offer full scope for phenothiazine, because the sheep treated with it were run in a paddock with other sheep harbouring many *H. contortus*, and were therefore exposed to heavy reinfestation. If all the sheep had been treated with phenothiazine, contamination of pastures with eggs would have ceased almost immediately, and reinfestation would have been limited to eggs and larvae present.

The outstanding value of phenothiazine is illustrated in Table 1, in which the approximate daily output of *H. contortus* eggs by each of the four groups is shown for the day of treatment and for four subsequent occasions. The figures were obtained by adding the egg counts for all sheep and multiplying by 600, in each group. The average 24-hour faecal output of sheep of the age and weight used in this trial is 600 grammes.

Table 1.—Total Output of *H. contortus* Eggs in Millions, by Each Group, for 24-Hour Periods on the Dates Shown.

Days after Treatment.	Date.*	Group 1. Phenoth.	Group 2. Carb. Tetra.	Group 3. Copper-Nicot.	Group 4. Control.
Day of Treatment	14.1.41	94·3	92·2	108·0	60·4
6th day	20.1.41	0·007	11·6	6·5	55·9
14th day	28.1.41	0·049	20·6	8·6	51·8
24th day	7.2.41	10·0	38·9	30·5	46·7
34th day	17.2.41	52·6	80·4	60·8	61·3

* Dates included to facilitate reference to Graphs 2 and 3.

The effect of phenothiazine in reducing contamination of pastures is striking. It should be noted that some sheep in groups 2, 3, and 4 received supplementary treatments on 28th January, 1941. These treatments undoubtedly retarded the return of egg output to pre-treatment levels, and without them the differences between group 1 and the other groups on 17th February, 1941, would probably have been even greater.

Carbon tetrachloride fails to control outbreaks because it is ineffective against immature worms (Gordon, 1939). Moreover, although it is highly efficient against adult worms it leaves enough females to contaminate pastures heavily with eggs. Its actual efficiency, therefore, is not as great as would appear from results based on percentage of worms removed or percentage reduction in egg count. An example will make this clear. Assuming a worm burden of 1,000 *H. contortus* females and an efficiency of 90 per cent. for carbon tetrachloride, 100 females will remain, and these will produce about $100 \times 5{,}000 = 500{,}000$ eggs per day.

Copper sulphate-nicotine sulphate mixture fails in some sheep because it is not swallowed into the abomasum. In a proportion of sheep this mixture fails repeatedly, and this permits continued contamination of pastures until the heavily infested individuals recover spontaneously or die. In the experiments described here it failed in three out of 24 sheep, and in one out of 25 sheep. Carbon tetrachloride can be used effectively to treat individual sheep which do not respond to copper-sulphate-nicotine sulphate mixture.

The occurrence of "self-cure" can readily lead to false impressions of the efficiency of treatments unless control sheep are included in field trials.

The present price of phenothiazine precludes its regular use against *H. contortus*. At current prices, a 15-g. dose of phenothiazine costs 2·4d. The corresponding dose of carbon tetrachloride (2 ml.) costs 0·16d., and of copper sulphate-nicotine sulphate mixture (25 ml. of 4 per cent. solution) costs 0·31d.

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Some Observations on the Stability of Lime-Sulphur During Dipping.

*By J. L. Hill, A.S.T.C., A.A.C.I.**

Summary.

A dipping trial was conducted in which 10,000 sheep were dipped in a diluted lime-sulphur dip containing approximately 1 per cent. polysulphide sulphur. On making up the dip with rain water there was a loss of approximately 8 per cent. in strength. During dipping the polysulphide concentration decreased, and generally the decrease became progressively greater as dipping proceeded. Some of this decrease is caused by the return to the dipping bath of the draining liquors, as it is in the draining pens that the dip is intimately exposed to the air.

1. Introduction.

During investigations into the control of a skin disease of sheep caused by the mite *Psorergates ovis* (Wormersley, 1941), which has been described by Carter (1941), an opportunity occurred to make observations on the stability of lime-sulphur dips while in use under field conditions.

Previous workers, when studying the stability of such dips, generally used "home-made" lime-sulphur concentrates, whose composition depends on many variable factors. Van Zyl (1926), however, used proprietary concentrates to study the variation of the polysulphide content of used dipping fluids which were left standing for periods as long as three months. The maximum number of sheep dipped in his experiments, however, was only 300. He found that during dipping, and also on standing, there was a decrease in polysulphide concentration, but it was slow enough to enable farmers with small flocks to use the dip left over from the first dipping for the second dipping operation, the interval between these being ten days. Hambrock *et al.* (1934), using both home-made and proprietary concentrates, observed, in many cases, marked decreases in the polysulphide concentration of lime-sulphur dips under field conditions. These workers attributed this decline to the effect of carbon-dioxide of the atmosphere, oxidation, and the introduction of suint constituents into the bath, the oxidation being caused by oxygen brought into the bath by the animal.

2. Preparation of Dip.

In this experiment 10,000 sheep, two to six weeks off shears, were put through a lime-sulphur dip containing about 1 per cent. polysulphide sulphur. This was made up from a proprietary concentrate containing approximately 20 per cent. weight by volume of polysulphide sulphur, by adding 5 gallons of concentrate to every 100 gallons of water. In addition, to assist in the penetration of the dip into the fleece, 150 millilitres of a surface active agent, Agral 3, were added to each 100 gallons of dip (equivalent to 0·03 per cent. W/V Agral 3).

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3. Chemical Observations on the Dipping Fluid.

During the course of dipping, samples were taken frequently from the dipping vat. These were immediately tested for sulphide sulphur by means of a field test devised by Chapin (1915). This test depends on the assumption that the polysulphide ratio remains fairly constant during dipping, and consists of titrating a known volume (25 ml.) of dipping fluid with a standardized iodine solution whose strength is so adjusted that 1 ml. is equivalent to 0·1 per cent. W/V sulphide sulphur. As a check on this field test, portion of the sample was brought back to the laboratory, and the sulphide sulphur content was determined by the Association of Official Agricultural Chemists' (1940) method.

It was found that the average amount of dip per sheep taken out of the bath was 0·5 gallon. In order to make up this loss, the dip was replenished with water and concentrate in appropriate proportions each morning before dipping commenced.

Rain water was used to make up the dip in the first place, but thereafter creek water was used. An analysis of the creek water gave the following results:—

Total solids in solution	272	parts	per million.
Ash	142	„	„ „
Sulphate (as SO_3)	25	„	„ „
Iron and aluminium (as Fe_2O_3 and Al_2O_3)	15	„	„ „
Calcium (as CaO)	26	„	„ „
Magnesium (as MgO)	35	„	„ „
pH (potentiometric)	7·50		

TABLE 1.—ANALYSES OF SAMPLES DURING DIPPING.

Date.	Number of Sheep.	Sample Number.	Sulphide Sulphur % W/V (1).		Monosulphide Sulphur (2) % W/V (AOAC).	Polysulphide Sulphur (1–2) % W/V.	Polysulphide Ratio.	Thiosulphate Sulphur % W/V.	Calcium % W/V (AOAC).	Additions to Bath.	
			Field Test.	AOAC Method.						Water (gallons).	Concentrate (gallons).
18.11.41	Nil	1	1·00	1·090	0·220	0·870	4·96	0·083	0·342	2,160	108
„	2,035	4	0·95	0·916	0·202	0·714	4·54	0·126	0·314	..	..
19.11.41	2,035	5	0·90	0·862	0·195	0·667	4·42	0·127	0·306	..	..
20.11.41	2,035	1A	0·95	0·945	0·203	0·742	4·65	0·117	0·324	600	30
„	3,060	2A	0·90	0·873	0·195	0·678	4·48	..	..	..	..
„	3,625	4A	0·95	0·985	0·212	0·773	4·65	..	..	930	46
„	4,975	5A	0·90	0·870	0·199	0·671	4·36	0·171	0·325	..	..
21.11.41	4,975	1B	0·95	0·975	0·208	0·767	4·70	0·134	0·316	540	27
„	6,480	4B	0·80	0·834	0·180	0·654	4·63	0·183	0·302	..	..
24.11.41	6,480	1C	0·80	0·791	0·175	0·616	4·52	0·148	0·296	380	19
„	6,905	2C	1·05	1·005	0·228	0·777	4·41	0·153	0·370	640	46
„	8,295	3C	0·95	0·976	0·204	0·772	4·78	0·189	0·346	..	..
25.11.41	8,295	1D	0·90	1·030	0·214	0·816	4·80	..	..	720	36
„	10,005	3D	0·85	0·858	0·184	0·674	4·66	0·218	0·310	..	..

It will be seen from Table 1 that on the addition of lime-sulphur concentrate to rain water, which had been stored in a tank for some time, the resultant dip had a polysulphide concentration of 0·870 per cent., whereas the theoretical figure should be approximately 0·95 per cent. We were fortunate to obtain samples from two other dipping operations, the dip being made up with rain water in each case. The initial polysulphide sulphur concentration from these two operations was 0·897 per cent. and 0·856 per cent., respectively. Thus there has been a loss of from 5 per cent. to 9 per cent. on dilution. This loss seems abnormally high, and from the available data must remain unexplained. That decomposition took place is shown by the thiosulphate sulphur content of 0·083 per cent. (Table 1), and 0·085 per cent. from each of the other two samples. However, Melvill (1922) states that there is a loss of about 3 per cent. strength on dilution if "ordinary" water is used, while Hambrock *et al.* (loc. cit.) report losses of up to 32 per cent., but the diluent used was creek water often having high total solids content.

Samples 4 and 5 of Table 1 show that the loss in polysulphide concentration in the dip standing overnight amounted to approximately 6 per cent.

From Table 2 it will be seen that the decline in polysulphide concentration was not correlated with the number of sheep passing through the bath. Moreover, with one exception, it will be seen that this decrease became progressively greater as dipping proceeded.

TABLE 2.—DROP IN POLYSULPHIDE CONCENTRATION AFTER DIPPING SHEEP.

Date.	Drop in Polysulphide Concentration per cent. W/V.	Sample Numbers (Table 1).	Number of Sheep Dipped.
18.11.41	0·047	1 –4	2,035
20.11.41	0·074	1A–2A	1,025
,, ...	0·102	4A–5A	1,350
21.11.41	0·113	1B–4B	1,505
24.11.41	0·005	2C–3C	1,390
25.11.41	0·172	1D–3D	1,700

On 24.11.41 there was only a decrease of 0·005 per cent., although 1,390 sheep were dipped. This may have been due to some of the sulphur, normally in suspension, redissolving in the dip bath since there was a corresponding rise in the polysulphide ratio.

An analysis of the fluid returning to the bath from the draining pens after 9,745 sheep had been dipped showed a polysulphide concentration of 0·622 per cent., a monosulphide concentration of 0·185 per cent, hence a polysulphide ratio of 4·37, a thiosulphate sulphur content of 0·212 per cent., and a calcium content of 0·321 per cent. After another 260 sheep had been dipped the bath showed a polysulphide concentration of 0·674 per cent. (sample 3D—Table 1).

It is in the draining pens that the dip is in intimate contact with the surrounding air, and, as Freney *et al.* (1941) have shown, sheep carrying 2½ to 3 months' wool return to the bath from ¾ to 1 gallon of drainings, per animal; it seems reasonable to suppose, therefore, that in this experiment the return of the draining liquors is the main cause of decrease in concentration.

If the polysulphide ratios in Table 1 were to be calculated from the respective calcium concentration, the figure obtained would, in all samples except No. 1, be too high. For example, sample 3D would give a ratio of 6·15. Obviously, some base exchange has taken place as insoluble calcium soaps have been formed from the suint, which is composed largely of potassium soaps of the lower fatty acids.

Samples were secured from two other dipping operations, but no detailed records were kept of the progress of dipping, and insufficient samples were taken for as detailed an examination as in the main experiment. For these reasons no account of the results are set out, but it can be stated that the chemical analyses from both operations agreed with those of the main experiment.

4. Discussion.

As there was only a gradual decline in the polysulphide concentration during the experiment, it was only once necessary to add additional concentrate to the dip in order to maintain a reasonably high polysulphide strength. Provided that proprietary concentrates and reasonably pure water are used, no trouble should be experienced from serious decreases in the concentration of lime-sulphur dips, but information is required regarding the behaviour of such dips when prepared with water of high total solids content, such as artesian bore water. It is hoped to seek this information later.

5. Acknowledgments.

I should like to thank Mr. N. P. H. Graham for the interest shown during the course of investigations, and also for the many helpful criticisms made during the preparation of this paper, I should also like to thank Mr. D. A. Gill, Mr. M. Lipson, and Mr. M. R. Freney for the suggestions made concerning the preparation of this paper.

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Increased Earliness of Flowering in Lettuce Through Vernalization.

*By S. G. Gray, B.Sc.Agr.**

Summary.

Sprouted lettuce seeds were kept at 4°C. for periods of 28, 42, and 56 days and subsequently grown in comparison with plants raised from untreated seed. Vernalized material produced seed stalks two to three weeks earlier than control material.

Experiments on vernalization were begun in the spring of 1941 with several species of vegetables, including some biennials and some annuals. This report discusses experiments with lettuce.

Material and Methods.

Two varieties of lettuce, Imperial D. and Imperial 847, were used. Six lots of seed of each variety, each lot containing about 150 seeds, were measured out. Three lots were germinated immediately and used for vernalization treatment, and the other three were kept and used later for controls. The three lots to be treated were placed on moist filter paper in Petri dishes on 25th August, 1941. On 26th August the seeds had sprouted. They were then placed in the refrigerator at 4°C. They were kept at this temperature for periods of 28 days (Lot 1), 42 days (Lot 2), and 56 days (Lot 3). Control material was raised for each lot by moistening seed on the day before the end of the refrigeration period, so that the control seedlings were apparently at about the same stage of growth as the vernalized ones when the latter were removed from the refrigerator. Seed was examined from time to time during the period in the refrigerator, and moisture added whenever necessary.

Lot 1 was taken from the refrigerator on 23rd September, lot 2 on 7th October, and lot 3 on 21st October. The material of Imperial D, lot 3, all died before the end of the 56 days, apparently as a result of insufficiency of moisture. Room temperature on the days when seed was removed from the refrigerator varied from 16°C. to 22°C. After removal the seedlings were left without handling for about 24 hours and then planted in flats in the glasshouse, control material being planted at the same time.

Lots 1 and 2 were transplanted to the field on 5th and 6th November, and lot 3 on 1st December. The plants were spaced 1 link apart, in rows 3 links apart.

Transplanting was done in dull weather, but this was followed by mostly fine and hot weather and frequent overhead waterings were necessary to keep the plants alive. Most of the plants survived transplanting, but many deaths occurred during the subsequent part of the season, owing to very high temperature. There did not appear to be any differential death rate between vernalized and unvernalized material, or between varieties.

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Results.

The first indications that plants were about to produce seed stalks were observed towards the end of December, and counts of bolted and non-bolted plants were made at weekly intervals from 3rd January to 24th January, 1942. Additional plants died during the period in which notes were taken, as a result of high temperature, so that the figures obtained are an approximate, and not an accurate, measure of the rate of bolting. The percentages of bolted to total plants at each date are given in the accompanying table.

TABLE 1.—EFFECT OF VERNALIZATION ON BOLTING OF LETTUCE.

Variety.	Treatment.	Percentage of Plants Bolted.			
		3rd January.	10th January.	17th January.	24th January.
Imperial D* ..	Vernalized 28 days ..	88	97	100	100
Imperial D ..	Control	0	11	71	100
Imperial D ..	Vernalized 42 days ..	88	100	100	100
Imperial D ..	Control	0	0	59	100
Imperial 847 ..	Vernalized 28 days ..	67	93	100	100
Imperial 847 ..	Control	0	3	52	100
Imperial 847 ..	Vernalized 42 days ..	62	97	100	100
Imperial 847 ..	Control	0	0	88	100
Imperial 847 ..	Vernalized 56 days ..	13†	93†	100†	100†
Imperial 847 ..	Control	0†	0†	0†	100†

* No plants of Imperial D. survived 56 days vernalization, as a result of drying out.
† Transplanted 25 days later than the remaining material.

The figures in the table show definitely that in every instance bolting of the bulk of the plants occurred from two to three weeks earlier in the vernalized than in the non-vernalized material.

There does not appear to be any important difference between treatment for 28 days, 42 days, or 56 days. Evidently the longer treatments have no more effect than treatment for 28 days. The longer treatments may be deleterious. The difficulty experienced in keeping material alive through the longer treatments supports this view.

The continuation of unfavourable weather rendered it impracticable to carry the material on to the seed-ripening stage.

Conclusion.

Keeping sprouted seed of lettuce at 4°C. for 28 days or more resulted in those plants producing seed stalks two or three weeks earlier than under ordinary conditions.

Top Rot of Maize, Sweet Corn, and Sorghum.

*W. V. Ludbrook, B.Ag.Sc., Ph.D.**

Summary.

1. The symtoms of a soft rot of the stem apex of maize, sweet corn and sorghum are described. They resemble those of top rot of sugar cane.

2. Various types of stunting or malformation of the tassel, upper leaves, and ear of maize may have a similar origin.

3. Top rot of maize, sweet corn, and sorghum was produced by inoculation of the stem apex with a bacterial organism isolated from naturally infected plants. Top rot of maize was also produced by inoculation with species of *Gibberella*.

4. The bacterial pathogen differed from each of a number of species of bacteria recorded as being pathogenic to maize or sugar cane, or causing soft rot of plant tissues. It is partially described, but has not yet been identified.

1. Description and Occurrence.

If a maize crop is examined during the month before tasselling, scattered plants may be found, of which the immature uppermost leaves are dead, dry, and bleached (Plate 2, Fig. 1). The remaining leaves appear normal. If the dead leaves are pulled out, the top of the stem usually accompanies them. The stem-apex, the immature tassel, and the bases of the uppermost leaves are destroyed by a wet soft rot with a characteristic offensive smell. On splitting the stalk longitudinally, a grey or brownish watersoaked rot of the parenchyma is seen descending from the apex (Plate 2, Fig. 2). Apical growth ceases, and no tassel or grain develops, but vigorous suckers are usually produced from the base of the plant (Plate 3).

A similar condition has been described in sugar cane, under the names of top rot or stinking rot (2, 6); sweet corn and sorghum were also found by the writer to be affected. Sorghum often develops laterals from the node below the rotted area.

Scattered maize, sweet corn, and sorghum plants with the tops killed in this way were found in several maize districts in Victoria and New South Wales during the past three seasons, but never in sufficient numbers to be of economic importance. What appears to be a similar condition in maize was also reported in South Queensland (1).

Maize plants with varying degrees of stunting or malformation of the tassel, upper leaves, and ear, or failure of the tassel to free itself from the tightly rolled upper leaves, are relatively common (Plate 4, Figs. 1 to 3). It is not claimed that these abnormalities are always the effect of apical infections before tasselling, but the results of inoculation experiments, to be described below, indicate that they may be caused by such infections, which are too mild or too late to rot the apex completely. Of 926 plants examined in two typical maize crops at Lindenow (Victoria), 2·6 per cent. showed abnormalities similar to those in Plate 4, Figs. 1 to 3. Table 1 demonstrates the adverse effect of these abnormalities on earing, and indicates that an appreciable percentage of barren stalks and nubbin ears may result from them.

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The "multiple nubbin" type of ear mentioned in Table 1 is illustrated in Plate 4, Fig. 4. It was produced experimentally by the writer in plants subjected to severe drought during tasselling and silking, and subsequently watered freely until maturity. These plants, which set very little grain, developed 24 per cent. of "multiple nubbin" ears on 290 stalks, as compared with 5 per cent. on 220 controls receiving ample moisture throughout the growing period. In 40 continuously watered plants from which the main ear was removed soon after pollination, 37 per cent. of the stalks bore "multiple nubbins," whilst none developed on the 40 control stalks. Such ears seldom set enough grain to be worth picking. It appears likely that any factor preventing the setting of grain on the main ear tends to cause the proliferation of secondary ears from nodes on the stalk of the main ear, if vegetative growth is sufficiently vigorous.

TABLE 1.—TYPES OF EARS PRODUCED BY (1) NORMAL MAIZE PLANTS, (2) PLANTS OF WHICH THE TASSEL OR UPPER LEAVES APPEARED TO HAVE BEEN INJURED, BUT NOT COMPLETELY ROTTED, BY INFECTION OF THE STEM-APEX WITH BACTERIA OR FUNGI.

Type of Ear Produced.	Percentage of Each Type of Ear Produced by—	
	(1) Normal Plants (132 examined).	(2) Apically Infected Plants (42 examined).
None	8·3	45·4
Very poor	7·6	19·0
Poor	6·0	11·8
Multiple nubbin	0·8	4·8
Normal	77·3	19·0

2. Factors Which May Predispose Maize to Top Rot or Allied Conditions.

Inquiry revealed that observant maize-growers were well acquainted with top rot, sometimes referring to it as heart rot. The following factors were mentioned by growers as being likely to bring about this condition, or the milder forms of injury illustrated in Plate 4, Figs. 1 to 3:—Careless harrowing or scarifying of seedlings, resulting in soil getting into the tops of the plants, or plants being trodden on; submergence of the plants for a few hours by a flood of insufficient duration to kill them; grub injury to the tops before tasselling. The writer was informed that one farmer scattered field pea seed amongst maize before tasselling, in order to grow the peas as green manure under the maize. Many seeds fell into the tops of the plants, where they germinated during wet weather, and subsequently died; this caused a high percentage of such plants to develop symptoms resembling those of top rot.

3. Isolation of Causal Organisms and Proof of Pathogenicity.

Numerous isolations were made during the past three seasons from naturally occurring top-rotted maize, sweet corn, and sorghum. Several types of bacteria were isolated, sometimes together with *G. fujikuroi* (Saw.) Wr. var. *subglutinans* Edwards. Occasionally this fungus occurred alone.

Before tasselling, the apex of the maize stalk, tightly ensheathed by the bases of the upper leaves, forms an excellent site for the development of bacterial or fungal rots, if the organisms are introduced into the cavity around the embryonic tassel by natural or artificial means. The rot usually originates in the immature tassel, and spreads into the stem apex and adjacent leaf-bases.

Some of the bacteria isolated from top-rotted plants were saprophytes, and others were weakly pathogenic. One appeared much more pathogenic than the others. The symptoms shown in Plates 2 and 3 and Plate 4, Figs. 1 to 3, were repeatedly produced in maize, sweet corn, and sorghum during two seasons by inoculations of the stem-apex with the latter organism. Similar symptoms were produced in maize by each of the *Gibberella* species commonly associated with root, stalk, and ear rots of maize in Victoria, viz., *G. zeae* (Schw.) Petch, *G. fujikuroi,* and *G. fujikuroi* var. *subglutinans*. Joint inoculations with these fungi and top rot bacteria were no more effective than those with fungi or bacteria separately.

The most consistent results were obtained by injecting an aqueous suspension of inoculum through the sheaths of the upper leaves at the level of the immature tassel, using a hypodermic syringe. A given amount of inoculum was much more effective when suspended in 10 ml. of sterile water per plant than in 1 ml. From 80 to 100 per cent. of the plants receiving 5 or 10 ml. of inoculum developed severe top rot. The same symptoms were produced, though in a smaller percentage of plants, by pouring about 20 ml. of inoculum into the uninjured apex of each plant, via the funnel formed by the bases of the uppermost leaves. In every experiment, controls similarly treated with sterile water or autoclaved inoculum were unaffected, except for mechanical injuries to the leaves caused by the hypodermic needle when this was used. Small yellowish-green streaks sometimes extended for a short distance from these injuries, but no rotting occurred.

Each of the organisms used for inoculation was repeatedly recovered in pure culture from the rotting tops, and was reinoculated and reisolated. Frequently organisms other than the one inoculated were isolated from the rotted tissue; *G. fujikuroi* var. *subglutinans* was the one most often obtained in this way. As the cavity into which the inoculum was introduced was open to the atmosphere through the crevices between the leaf-bases, it was probably not sterile before inoculation, and it cannot be claimed that top rot was produced by any one organism alone; however, the injection of sterile water or sterilized inoculum into this cavity never caused top rot.

4. Description of the Bacterial Pathogen.

As mentioned above, one of the bacteria isolated from top-rotted plants was outstandingly pathogenic; this was selected for further study. It has not yet been identified. Its characteristics did not agree with those of *Phytomonas rubrilineans* (Lee et al.), Bergey et al., or those of *Bacillus pyocyaneus saccharum* Desai (2), which are reported to cause top rot or stinking rot of sugar cane, nor with those of *Phytomonas dissolvens* (Jones) Bergey et al (4, 5), the causal organism of bacterial stalk rot of maize. It differs from all the common soft rot bacteria enumerated by Dowson (3) and Elrod (4).

The organism studied by the writer is a minute motile Gram-negative rod, forming small, circular, yellowish-white, raised, glistening, slightly translucent to opaque colonies on agar; the margins are slightly crenulate, and may become amoeboid in old, widely-spaced colonies. A freshly-isolated culture of the organism liquefied gelatine rapidly in plates, and slowly, from the surface down, in stab cultures. Acid and gas were formed with sucrose, mannite, or dextrose, but not with lactose or maltose, either in peptone water or in the mineral solution used by Dowson (3). Litmus milk was coagulated without acidification. Little or no indol developed during seven days in peptone water; a strong nitrite reaction was obtained after two days in a solution containing sodium nitrate and other mineral salts plus glucose. Slices of fresh potato, onion, carrot, tobacco stem, and cucumber were rotted very rapidly.

It is thought possible that some of the other bacterial cultures isolated by the writer may also be highly pathogenic when freshly isolated; some isolates were unavoidably held in culture for several months before being tested. The isolate described above showed a marked decline in pathogenicity when maintained in artificial culture.

5. Acknowledgments.

The writer is indebted to Miss A. Osmond for assistance in the study of the bacterial pathogen, and to Dr. E. T. Edwards for the information that top rot of maize could be produced by inoculation of the stem apex with the species of *Gibberella* commonly associated with root, stalk, and ear rot.

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Additional Note.

Since the foregoing was submitted for publication, a paper entitled "Heritable characters in maize. Knotted Leaf" (Bryan, A. A. and Sass, J. E.—*J. Hered.* 32: 343-346, 1941), has come to the writer's notice. Some of the malformations observed in the upper leaves of plants inoculated with top rot organisms resembled those characteristic of the inherited condition described as "Knotted Leaf" by these authors. They differed from it in several respects, e.g., in the occurrence of yellow streaks and necrotic patches in affected leaves. As they did not occur in non-inoculated controls, it is unlikely that they were of genetic origin.—W.V.L.

"Density" and Some Related Characters of the Fleece in the Australian Merino.

*By H. B. Carter, B.V.Sc.**

Summary.

The importance of the density of the fibre population in the skin of the Merino is discussed briefly in popular terms, and its contribution to compactness and weight of fleece indicated. Attention is directed especially to the hair follicle groups in the skin of sheep as the units or building stones of which the fleece is constructed. Such groups not only determine the fibre population density of the skin by their individual size and number, but also largely influence the uniformity of the fleece, and its external appearance.

Most sheepmen in this and other countries consider density to be the impression of compactness received when the fleece is grasped in the hand. Its importance to the grazier is summed up in the phrase "What fills the hand fills the bale." If fleece density is to be judged correctly it is necessary to know just what does fill the hand.

The most important contributing factor to compactness in a fleece is the number of fibres growing on a unit area of skin, such as a square inch. Next in importance are the average thickness of the fibres present and their degree of stiffness or rigidity. Finally, the amount of "yolk" and dirt surrounding the fibres and whether the "yolk" itself is firm and sticky or soft and fluid make their contribution. All these factors, operating together, determine the main feeling of compactness when the fleece is actually handled.

However, the judgment of fleece density does not depend alone on impressions received by touch. Visible signs can supplement the "educated finger." For example, when the fleece is parted the amount of bare skin showing and the resistance offered when the fleece is opened, provide useful indications of density. The compactness of the tip or its "closure," as the Americans term it, is also a general guide. This sign, however, must be interpreted very carefully because the length of the staple alone may cause confusion, i.e., a short staple may appear more compact than a longer one.

It is clear, then, that fleece density is a very complex character. Experiments have shown that it is perhaps the most difficult character of the fleece to appraise accurately, even when time and care are taken. But to understand fleece density and the factors which may affect it, brings us very near to a complete grasp of what determines individual fleece weights.

Increased density is desirable for two different but related purposes. First, an increase of fleece density in a flock may be, and usually is, desired to increase the average "cut" per head. For this purpose, it is necessary to increase the number of fibres per square inch so far as possible and to maintain their average length and thickness. Second, increased density may be needed to produce a more weather-resistant fleece. For this purpose it is important not only to have a dense fibre

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population of sufficient thickness and rigidity, but also an adequate but not excessive amount of "yolk." For either purpose, improvement depends on the density of the fibre population, i.e., the numbers per square inch.

There is great individual variation among Australian Merino flocks in the number of fibres per square inch of skin. Average fibre counts as low as 15,000 and as high as 80,000 fibres per square inch have been found in mature Australian Merinos of various types. Fine-wool types tend to have more fibres per square inch than strong-wool types, but this is not an invariable rule. Merinos from our best studs may average more than 50,000 fibres per square inch, good flock animals rarely more than 40,000, whereas the majority of Australian Merinos probably average only about 30,000 fibres to the square inch. Good classing will generally remove the sheep with the lowest fibre counts, but it is surprising how many animals with low fibre counts can be found even in some of the best classed studs. It is very doubtful whether an expert classer at present can distinguish between two animals in which the difference in fibre counts is much less than 15,000 fibres per square inch. This being so, it is perhaps not so surprising that greater uniformity has not been attained and that we find relatively great variation in the density of the fibre population among our flocks.

Among South African Merinos the range is about the same as for the Australian Merino, but the average density is probably slightly less. In the United States the average number of fibres per square inch in the Rambouillet, the American Merino, and the Delaine Merino is probably very much less than in this country. Figures exceeding 40,000 fibres per square inch are rare, and most values appear to be somewhere between 15,000 and 35,000 fibres per square inch. It is doubtful whether the importation of American Merinos into Australia some 40 or 50 years ago added anything to the number of fibres per square inch already present in the Australian Merino of that period in spite of all that has been written to the contrary on both sides of the Pacific. A study conducted over a period of seven years at Ohio Experiment Station and reported in 1936 showed that imported Tasmanian Merinos grew nearly 40 per cent. more fibres per square inch than the equivalent grade of American Merino, at all ages and under the same pastoral conditions. Other comparative tests have been made with similar results.

There is much room for improving the efficiency of Merino wool production per sheep in our studs and flocks by increasing the average number of fibres per square inch. One hypothetical example will suffice. The average greasy fleece weight for sheep of all breeds and ages in Australia is about 9 lb. If we allow an average "yield" of 50 per cent. this is equivalent to 4½ lb. of clean-scoured wool per sheep. This quantity of wool could be produced by a Merino with a wool-growing skin surface of slightly more than 10 square feet, and a fleece of average 64's spinning count, a staple length of 3 inches, and a density of 30,000 fibres per square inch. In other words, our average fleece could be produced by a poor type of Australian Merino, which would certainly be culled from any of our studs or better flocks.

To increase the number of wool fibres grown by such an animal from 30,000 to, say, 50,000 fibres per square inch (i.e., nearer the stud figure) would result in a clean-scoured fleece weight of 7½ lb., an

increase of 3 lb. of wool substance. If an average yield of 50 per cent. is allowed again such an animal would produce a greasy fleece weighing 15 lb.—a very fair cut for a good medium-wool ewe.

The study of fleece density, however, tells us more about the sheep than whether it is likely to cut a heavy fleece or not. There is much to be learned about the quality of the fleece. Some fleeces have greater uniformity among the fibres than other fleeces, and this is not due to chance. The fleece is not a disorderly arrangement of unrelated fibres. There is system and order throughout, and this is apparent very early in the development of the unborn lamb or foetus.

Variations in density follow a plan in which the densest regions of the fleece tend to be those where fibres develop first. This is not peculiar to the sheep alone. It is a fairly general biological principle. Thus we tend to find the greatest number of fibres per square inch on the head, the density gradually decreasing as we pass along the neck and back toward the tail. There is also a gradual reduction in the number of fibres per square inch passing downward over the sides towards the belly, where the fibres are sparsest. Sheep vary in the way these changes occur from point to point. In the best animals there is relatively little difference between the areas of high and low fibre counts. In others the differences are so marked that they are easily seen.

We can now consider the wool-fibre population in a little more detail. In sheep, as in all hairy-coated animals, the fibres are arranged in microscopic clusters. These groups can only be examined by special methods in the laboratory, but they probably contain most of the important secrets of the appearance and qualities of the fleece. They are the units or building stones of which the fleece is constructed, and are found in the fleeces of all species and breeds of sheep. From a study of the fibre group we find that however uniform a Merino fleece may seem to be it is actually composed of two different types of fibre, which occur in definite proportions within each little group according to the age, type, or breed of sheep and the region of the body.

To understand the fibre group we must return to the unborn lamb. During the first three and a half months of the ewe's pregnancy, before any fibres have burst through the lamb's skin, the immature hair follicles tend to be arranged in groups of three, called "trio" groups. Each follicle in the "trio" group has a sweat gland and small muscle attached to it. Because these "trio" follicles are the first to develop they are later known as "primary" follicles and produce "primary" fibres. During the last month or six weeks before the lamb's birth small follicles rapidly appear between the three primary follicles of the "trio" group. These are called "secondary" follicles, and produce the "secondary" fibres. Secondary follicles do not possess either a sweat gland or a muscle. The only accessory they possess is a small sac-like wax gland, a feature which they share with the primary follicles, and which produces the greasy portion of the "yolk."

In the birthcoat of the Merino lamb the primary fibres are the "mother-hair" or "kemp" fibres, which are shed more or less rapidly. The same primary fibres form the "outer" coat of wild sheep. The secondary fibres are the soft, fine fibres of the lamb fleece—the so-called true wool fibres. In the adult Merino these generally comprise about 95 per cent. of the fibres present. They are the same fibre type as the

"under" coat of wild sheep. Once the primary fibre, "kemp," or "mother-hair" is shed another fibre usually takes its place in the same follicle. In the Merino this second generation of fibres usually cannot be distinguished from the secondary fibres. In some Merinos, however, the first primary fibre may be followed in the same follicle by another, as "kempy" or "hairy" as the original "mother-hair." These may grow into long thick fibres projecting above the fleece as a sort of halo, producing a "fuzzy" tip. Such fibres often have a central core (the medulla or pith) of the same type as the kempy primary fibres on the face and legs. In some other breeds well marked differences between primary and secondary fibres are normally found. In the Merino the tendency is for any such difference to be comparatively small, so that in the most uniform animals the fleece seems to consist of one fibre type only, and a level blocky tip surface is the result.

It may now be seen why the follicle group is so important. The nature of the group determines the relative number and size of the primary and secondary fibres. In other words, the fibre group is the unit on which the uniformity of the fleece as well as the number of fibres per square inch finally depends. Each group consists typically of three primary fibres (the original "trio" group of the unborn lamb) and a variable number of secondaries, depending mainly on the animal's inheritance, though feed and other conditions can affect the number to some extent.

Of all domestic sheep the Merino has the largest fibre group and densest fleece. This may consist of three primaries and as many as a hundred or more secondaries. On the other hand, breeds such as the Border Leicester or Lincoln have very small groups, consisting of the usual three primaries, but only about fifteen or eighteen secondaries. In a general way large groups may mean dense uniform fleeces. Small groups generally mean slack, less uniform fleeces.

When cross-breeding occurs between two such extreme types as a Merino and a Border Leicester or Lincoln, we may get a fibre group nearly equal in size to that of the Merino, but in which the primary fibres tend to be distinctly larger than the secondaries. This sort of group is very characteristic of many cross-breds or of any "breed" in which a mixture of farily extreme types has occurred at some time in its past history and has been followed by a period of inbreeding.

Results of the examination of many samples of Australian Merino wool from this point of view lend strong support to the suggestion that the Australian Merino (mainly the medium and strong-wool types) is the product of an earlier period of cross-breeding. There is also historical evidence that this is so. It is now fairly well established that the Leicester, Lincoln, Cotswold, Romney Marsh, and, to a slight extent, the Southdown, and even perhaps some unknown Asiatic breeds, are to be linked with the early Spanish Merino as the foundation stock of many of our most important Australian Merino strains. In fact, it would not be too much to say that many good qualities of the modern Australian Merino owe more to the cross-breeding era in its history (i.e., up to about 1850) than to any subsequent importation of pedigreed stock from other countries, such as the United States of America, Germany, and France. Only on this basis can many present-day characteristics of the fleece and body conformation be understood.

Some Experiments on the Structure and Behaviour of the Cortical Cells of Wool Fibres.

*By E. H. Mercer, B.Sc.**

Summary.

The cells of the cortex of animal fibres are the seat of the elastic properties of the fibres. These cortical cells can be made to stretch, set, and supercontract in a manner analogous to the whole fibre.

The supercontraction of the intact fibre is discussed in the light of evidence obtained from a study of the supercontraction of isolated cells. Within the cortical cell a network of resistant fibrils is demonstrated, and an attempt is made to explain some features of supercontraction as arising from a contraction of this network following the loosening of "set" within the cell by the action of the reagents used. The cortical cells originate as spherical cells at the base of the fibre follicle, and are elongated and set by keratinization as they are forced out of the follicle. Supercontraction of cells is looked upon as the reversal of this process of elongation and setting.

1. Introduction.

The problem of the structure of the keratin fibres has been approached from two directions—(i) by the study of the elastic properties of whole fibres carried out mainly by Speakman; and (ii) by the X-ray researches of Astbury, which have cast light on the ultimate molecular structure of the fibre. The most remarkable property of the keratin fibres is their range of extensibility. Fibres can be made to double their length in steam, and by special treatments can be induced to supercontract to about half their original length. They thus possess an elastic range of about 300 per cent. This property has been explained by Astbury and Woods (1933) directly in terms of the folding and unfolding of the long polypeptide chains of the protein. In fully extended hair, or β-keratin, the chains are fully extended (Fig. 1*a*); in normal hair, or α-keratin, they are folded to be half as long (Fig. 1*b* and *d*). More elaborate folding is thought to occur in supercontracted keratin, and for this form the structure shown in Fig. 1*c* has been suggested.

Attention has been focussed on the attempt to explain the properties of the whole fibre immediately in terms of its component molecules, with the result that observations which can be made on microscopically visible fibre components have been neglected. With the exception of Speakman's earlier papers (1926, 1931*a*), Woods' work (1938) on the cortical cells from wool; and a recent paper by Hock, Ramsey, and Harris (1941) the vast field between molecular sizes of the order of Angstroin units and gross fibre sizes has attracted little attention.

The present paper describes observations on the cortical cells of wool and their internal structure.

* An officer of the McMaster Animal Health Laboratory, Sydney. The work was carried out while the author was engaged on a joint investigation of wool fibres by the Division of Animal Health and Nutrition and the Division of Industrial Chemistry.

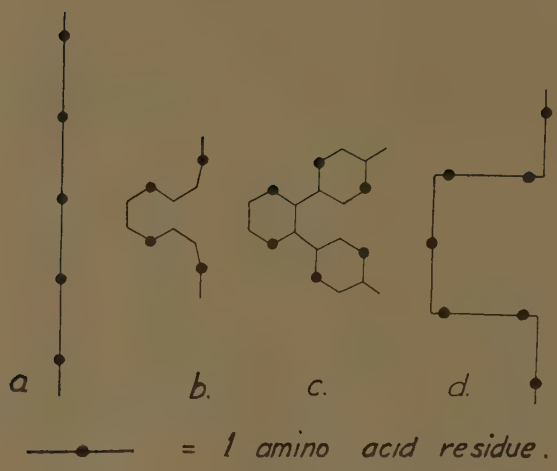

FIG. 1.*

(*a*) Fully extended polypeptide chain, β–keratin structure.
(*b*) Astbury's original α–keratin structure.
(*c*) Astbury's suggested structure for supercontracted keratin.
(*d*) Astbury's (1941) newly proposed structure for α–keratin.

The cortex of keratin fibres, which is recognized as the basis of their elastic behaviour, is composed of long, thin, flat cells, about 100μ in length and tapering at each end (Plate 6, Fig. 1). These cells were studied by Waldeyer (1882) and Nathusius (1894), and by more recent workers, but there is still some doubt as to their exact morphology. The cells are approximately spherical when formed at the base of the follicle and are elongated as they are extruded through the constricted portion of the follicle. Keratinization is completed after they have acquired their final length and shape, and serves to set them in their elongated form. As the elongation proceeds the nuclei progressively disappear until finally only the modified cytoplasm remains to form the so-called "cortical cell" as isolated from the fully keratinized fibre. The partial longitudinal alignment of the keratin, indicated by X-ray photographs of fibres and cells, probably results from the spinerette-like action of the follicle. Speakman (1926) suggested that the cortical cell was the elastic unit of the fibre, and Woods (1938) established the truth of this hypothesis by demonstrating that cells, isolated from fibres which had been stretched and set, had increased in length almost in proportion to the increase in length of the whole fibre. The present paper describes the use of naturally pigmented fibres to illustrate the extension of cells, and methods of producing supercontraction in isolated cells. Observations on the internal structure of cells, which suggest an explanation of some peculiarities shown by cells in super-contraction, are also described.

* Neurath (1940) criticized structures (*b*) and (^) on stereo-chemical grounds. Structure (*d*) has been advanced by Astbury to replace (*b*). No new structure for supercontracted keratin has been advanced by Astbury.

2. The Extension of Cortical Cells.

The material used in these experiments was a naturally pigmented merino wool in which the black pigment was located in granules about 0·6μ in diameter. The greater part of the pigment lies within the cortical cells, and, as can be seen from Plate 5 (*a*), the granules frequently show a linear and regular arrangement like a string of black beads, which allows the degree of stretching *within* the cells to be followed in addition to the total increase in length of the whole cell.

Experimental.

Bundles of about 50-100 fibres were stretched to definite limits in boiling M/50 sodium borate solution and were set by boiling for a further 30 minutes. This medium was chosen because Speakman (1936) has shown that set occurs most rapidly, and is most permanent, at pH 9·2. After setting, the fibres were washed and put into the retting solution.

The fibres were retted at 35°C. with a 0·25 per cent. trypsin solution buffered by phosphates to pH 8·6 (Burgess, 1934). The wool disintegrates within a few days, when gentle scraping or shaking with beads frees the cortical cells. These may then be separated from scales and debris by sedimentation and washed free from buffer solution. The length of the cells was measured by micro-projection of a sample mounted in water.

The results will not be discussed in full since they merely serve to confirm those obtained by Woods (1938). Plate 5 shows (*a*) a normal cell and (*b*) a cell isolated from wool stretched and set at 80 per cent. increase in length. The increased spacing between the pigment granules in (*b*) shows that the cell has stretched uniformly throughout its length, but the pigment granules do not appear to have altered in shape to the same degree. This is of interest in view of a recent paper by Hardy and Plitt (1941), who have demonstrated the existence of small "particles" of keratin about 0·6μ in diameter within the cortical cells. They suggested that these "particles" could take up pigment and appear as the pigment granules. Since the pigment granules do not share in the extension of the cell, they cannot be regarded as consisting of keratin impregnated with pigment.

Woods found appreciable differences between the increase in length of stretched fibres and the increase in length of the cells isolated from the stretched fibres. Similar differences were found in the present experiments. Woods pointed out that this phenomenon meant either that an actual difference did exist, part of the whole fibre extension being contributed by an inter-cellular phase, or that the cells were partly relaxed during retting. To decide between these alternatives an attempt was made to measure the extension of the cells *in situ* without retting. This is possible with lightly pigmented wool, because the characteristic arrangement of granules enables the cells to be located under oil immersion in the intact fibre (Plate 6, Fig. 2). The outlines of the cells cannot be seen, but by choosing well-defined chains of pigment granules within the cells the length and extension of these can be measured. With great care it was found possible to identify, after extension, the actual chains measured before extension, if this had not exceeded about 30 per cent. Identification is facilitated by knotting the fibre in two

places about 1 mm. apart, in order to define a small portion, and by preventing rotation by fastening the fibre beyond the knots with celluloid cement to two strips of paper which press against the slide on which the fibre is mounted. Fragments of medulla were found useful as guides when attempting to find the same cells after extension.

The measurements were made with a micrometer eyepiece to the nearest micron. Since the chains of granules were usually 20 to 30μ long, the error in the direct measurement is rather large, and too few measurements were made to enable a statistical analysis to be made. Nevertheless, it appeared that at least the greater part of the apparent difference in length increase between the isolated cells and the whole fibre results from a partial relaxation of set of the cells during retting.

There can be little doubt that the cortical cell may be accurately described as the "elastic unit" of the fibre.

3. The Supercontraction of Cortical Cells.

The folded polypeptide chains in α-keratin (Fig. 1*b* or *d*) are thought to be joined by cross-linkages derived from the side chains of the substituted amino acids. The most important of these appear to be salt linkages arising from a combination between basic and acidic substituents, and disulphide linkages arising from cystine residues shared between adjacent chains. It is regarded as strong support for this theory that supercontraction, interpreted as the development of more elaborate molecular folding (see Fig. 1*c*), is produced by reagents which can break both disulphide and salt linkages and thus free the main peptide chains. Dilute sodium sulphide solutions, for instance, were found by Speakman (1931*b*) to cause a marked swelling and, subsequently, a contraction of about 20 per cent. when the fibre was washed free from sulphide. Supercontraction in *isolated* cortical cells may be induced by similar reagents, as will now be described.

Experimental.

The cells were treated either in aqueous suspension, or mounted on a microscope slide, in which case the contraction could be watched. Plate 7, Figs. 1 and 2, illustrates the results of an actual experiment. A group of cells was photographed in air (Fig. 1) and then covered by a drop of ethyl alcohol containing 10 per cent. potassium hydroxide and 7 per cent. water. The second photograph (Fig. 2) was taken after 90 seconds and shows the cells in a contracted and swollen condition. Aqueous solution of 4 per cent. sodium sulphide acts with equal rapidity. Weaker alkaline solutions, such as 1 per cent. sodium carbonate, readily contract cells which have been previously brominated or chlorinated. This result may be contrasted with the action of such solutions on chlorinated *fibres,* namely Allworden's reaction followed by gelation of the surface.

The supercontraction of cells, produced within a few seconds in this way and watched under the microscope, is an even more impressive demonstration of the inherent contractility of keratin than observance of the same phenomenon produced in whole fibres.

The contracted cells are about 45 to 50μ long and 10 to 15μ wide when measured in water. The percentage contraction (about 50 per cent.) is of the same order as the maximum contraction found in whole

fibres (40 per cent.). The difference may be due to the restraining effect of the cuticle and neighbouring cells in whole fibres.

The very close parallel between the extensibility of fibres and cells is clear from these experiments on the supercontraction of cells by reagents similar to those producing supercontraction in fibres; from the experiments made by Woods; and from those described in the previous section of this paper. The cortical cell possesses the same remarkable extensibility and contractility as the intact fibre.

Although Astbury's conclusion, that supercontraction is evidence of molecular contraction, is probably true in the broad sense, the full details of the process are by no means clear. The X-ray photographs of supercontracted fibres made by Astbury and Dickenson (1940) were not decisive. A somewhat distorted β-type of photograph, characteristic of *stretched* or compressed keratin, was obtained from their *supercontracted* fibres. They ascribed this to stresses set up in one part of the fibre complex by the contraction of other parts. This implies that supercontraction is relatively complex, and that the heterogeneity of the fibre plays a part. The ony remaining evidence that suggests molecular contraction is the over-all shortening of fibres and cells. A study of cortical cells in the act of contraction should cast light on this phenomenon. Particularly by the use of pigmented cells should some information of internal cell movement be obtained.

The pigment granules in cells of normal length are aligned in chains which are arranged parallel to the axis of the cell and also to the axis of the fibre (Plate 5*a*). The movements of the granules however can be followed only to a limited degree because the reagents used usually decolourize the pigment in a short time and ultimately dissolve the cell. After supercontraction the granule chains are usually found to be twisted and contorted to some degree. The individual granules in a chain are closer together, indicating a contraction of the material between the granules or of that in which the granules are imbedded. Some chains of granules are so far displaced as to give the appearance of lying across others. These changes are not easy to photograph at the magnification required, but a close examination of the cell shown in Plate 5(*c*) illustrates the point. It is clear that the simple hypothesis of a homogeneous bundle of molecular chains undergoing contraction will not serve to account for the complex internal derangement shown.

It has long been known that the cortical cells contain fibrils of a variety of keratin more resistant to destructive reagents than the cell matrix. These fibrils may be seen in heavily retted cells, and were isolated in a fragmentary condition by Nathusius by the prolonged action of ammonia on wool. The arrangement of these resistant fibrils may be demonstrated by treatments designed to etch away the less resistant matrix. For instance, cells may be fastened to a slide by means of an albumen adhesive, saturated with bromine by means of bromine water, and then warmed with 1 per cent. sodium carbonate. The results of this treatment are uneven, but in the remains of many cells, after staining with methyl violet, the fibrillar structure may be seen. The albumen adhesive appears to impede the supercontraction which would normally result from this treatment.

Plate 6, Fig. 3, shows a portion of a cell treated in this way. The fibrils are seen to be longitudinally arranged within the cell with what appear to be numerous cross links giving the impression of a network

stretched in the direction of the cell axis. This feature of the fibrillar structure has not been commented on by other observers, although one of Nathusius' drawings shows a branch structure of the type seen in the present preparations. It is possible that the movements of the fibrillar structure gives rise to the internal cell movements observed during contraction. It is also possible that the fibrillar structure, being more resistant than the cell matrix, may retain sufficient rigidity to exert some control over the change in shape and length of the cell. Efforts to demonstrate fibrils in supercontracted cells were unsuccessful because attempts to etch the cells in this condition readily dissolved them. Nevertheless an impression of the fibrillar structure in a more open and crumpled condition could be obtained by raising and lowering the microscope focus.

Finally it may be mentioned here, that in undergoing supercontraction the cortical cells are, in a sense, reverting to the original form of the cells at the base of the fibre follicle. As may be seen in Plate 8, which illustrates a follicle from the skin of a guinea pig, the cells destined to become the cortical cells of the fully keratinized fibre are roughly spherical when first formed, and are elongated as they are extruded from the follicle. The zone of elongation, marked *AB* in Plate 8, in fresh unfixed sections yields a positive nitroprusside reaction indicating the presence of free sulphydryl groups (Girond and Bulliard, 1930). The protein in this zone is still in a plastic pre-keratinous condition, and the longitudinal molecular alignment demonstrated by X-rays and by polarized light may be ascribed to the flow occurring as the cells are elongated.

The final stage of keratinization, shown by failure to yield the nitroprusside reaction and by staining with picric acid, occurs at a higher level in the follicle where the inner root sheath first breaks away from the fibre (see Plate 8). Beyond this point the medulla, if present, rapidly shrinks in size owing to desiccation. Keratinization thus occurs *after* the cells have been elongated and serves to "set" them in the form in which they can be isolated from the fibre by retting. Other structures, which may be present in the original cell, for instance the precursor of the fibrillar structure, will also be stretched and longitudinally aligned as the cell stretches. The cell is set in its final state by keratinization, and treatment by reagents which disrupt the side linkages to which the peculiar stability of keratin is ascribed, would loosen the set and thus allow a relaxation towards the original shape of the cell. This, as seen in isolated cells and in fibres built from cells, would appear as supercontraction.

During the elongation and keratinization of the cells the cell nuclei completely disappear. During supercontraction an opening or thinning is sometimes observed at the centre of the cell which may represent the space originally occupied by the nucleus. Similar openings at the centre of the cell have been observed by Hock, Ramsey, and Harris (1941).

4. Acknowledgments.

I am very much indebted to Mr. E. Parrish for making the photomicrographs, and to Mr. R. Rushworth, who prepared the skin sections.

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A Note on the Biological Analysis of the Merino Fleece.

By H. B. Carter, B.V.Sc. and J. L. Hill, A.S.T.C., A.A.C.I.**

Summary.

The results are given of a combined histological and chemical study of the skin and fleece samples from nine ewes representing widely different types of Australian Merino.

1. Introduction.

Very little is known of the assortment and range of characters contributing to the gross weight of raw fleece produced by various types of the Australian Merino. Freney (1940) has reported the analysis of raw fleece samples from eight Merino sheep and demonstrated, by chemical methods, the main regional variations in the production by the skin of dry wool, wax, and suint. In this study, he emphasized the importance of expressing the quantities of the physiological skin products (*a*) as percentages of the weight of dry wool in the sample, and (*b*) as weights per unit area. Apart from this investigation by Freney, no data are available for the Australian Merino which show the main variations in the physiological constituents of the raw fleece.

The present note is intended to present briefly:—

(i) The results of histological measurements on the skin and fibres, with a general chemical analysis of the raw fleece produced at the same site on the body of nine widely different types of Australian Merino.

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(ii) The computed quantities of the main physiological constituents of the raw fleece (wool, wax, and suint) produced by the nine sheep expressed as weight per unit area per unit length of fibre.

No such biological analysis has, to our knowledge, been made for the Australian Merino, and it is considered that the results may have some value in a comparison with the fleece characters of the Merino in other countries. The analysis is also intended to emphasize the complex association of factors which must be appreciated fully in any biological study of raw fleece production in sheep.

2. Material and Methods.

(i) The Sheep.

The nine sheep were originally selected for analysis to show one thing clearly, namely, a wide range in yield of clean dry wool. The fleece samples on which the selection was based were estimated to show yield differences of 5 to 10 per cent. over a range lying approximately between 20 per cent. and 75 per cent.

The experimental animals may be divided into three groups::—

Group 1 (Sheep Nos. 1, 2, and 3).—Ewes from the historic Camden Park flock, representing an early type of the Australian Merino. They were selected to represent low-producing animals (by modern standards) of extreme fineness.

Group 2 (Sheep Nos. 4, 5, and 6).—Ewes from a Western New South Wales flock of "Haddon Rig" strain representing an unselected line of modern medium-wool Merinos.

Group 3 (Sheep Nos. 7, 8, and 9).—Ewes from a South Australian flock of the "Bungaree" strain, representing an unselected line of modern strong-wool Merinos.

The ages of the sheep varied from eighteen months to five years. The plane of nutrition under which the sheep were run at the time of sampling was not uniform. Group 1 was maintained under average paddock conditions near Sydney. Groups 2 and 3 were kept under confined pen conditions on an ample diet, of which that provided to Group 3 was of an exceptionally high quality.

As to type, all nine animals were approximately equal in being extremely "plain" or smooth-skinned even to the complete absence of any visible neck or breech folds. In general size, however, there was much variation, and the approximate range in shorn body weight was from 70 to 80 lb. in Group 1 to 130 to 140 lb. in Group 3.

(ii) The Skin Samples.

These were biopsy specimens removed from the same anatomical point on the body of each animal, i.e., along the line of the heart-girth, 6 to 7 inches lateral to the median dorsal line. Histological serial sections were prepared and examined, using the general technique described by Carter (1939).

(iii) The Fleece Samples.

These were the samples removed by close clipping from exactly the same patch of skin used for the histological study. The original raw weight of the samples analysed ranged from 4 to 7 g. They were all

an approximate twelve months' growth. No attempt was made to fix either a unit area of skin or a growth period for these samples. The method of direct histological measurement used made it possible to assume standard values for fibre length and surface area of skin, since the other significant variables (density of fibre population and fibre thickness) were independently determined.

The method of chemical analysis applied to the raw fleece samples was similar to that of Freney (1940), except that carbon tetrachloride was used instead of chloroform as the organic solvent in the Soxhlet extraction. Thus, in this experiment, the following definitions should be noted:—

(*a*) *Wax.*—That portion of the raw fleece sample extracted with boiling carbon tetrachloride.

(*b*) *Suint.*—That portion of the raw fleece which after Soxhlet extraction with carbon tetrachloride is removed by cold water.

The yield of clean dry wool (Table 2) is expressed in two ways:—(*a*) as a percentage of the original raw dry sample, and (*b*) as a percentage of the raw dry sample minus dirt (i.e., eliminating epithelial debris, adventitious foreign matter, and moisture).

The amounts of wax and suint are expressed in Table 2 as percentages of the weight of clean dry wool in the sample. These may also be referred to as indices or ratios (Freney, 1940).

The determination of mean fibre "diameter" (Table 1) was made at a magnification of x 500, using a Bausch and Lomb microprojector.

Table 1.—Data Derived from Histological Sections of Skin and Fibre Measurements.

Sheep No.	Mean fibre thickness (μ).	Mean number of fibres per unit area of skin (cm.^{2}).		Ratio. $\frac{P+S}{P}$	P%	Density index. $n\pi\left(\frac{f}{2}\right)^2$ (mm^2 or %).
		Total ($P+S$) per cm.^{2}	Primaries (P) per cm.^{2}*			
	(f)	(n)				
1	14·65 ±0·186	4,600	473	9·7	10·3	0·78
2	14·35 ±0·162	4,280	355	12·1	8·3	0·69
3	14·58 ±0·189	8,630	556	15·5	6·4	1·44
4	28·00 ±0·297	2,280	475	4·8	20·9	1·41
5	22·52 ±0·224	7,120	445	16·1	6·2	2·84
6	18·21 ±0·176	9,400	320	29·3	3·4	2·45
7	28·58 ±0·370	5,600	360	15·5	6·5	3·60
8	28·71 ±0·434	8,000	500	15·9	6·3	5·18
9	27·17 ±0·554	8,900	480	18·6	5·4	5·17

* Equivalent to number of sudoriferous or "sweat" glands per cm.^{2}

Slides of fibre fragments were prepared from snippings made across the base of the staple, i.e., as near as to skin level as possible. The original material was carefully zoned, sub-samples drawn from each zone, and a composite sample used to provide the snippings for slide preparation. One slide preparation was used for each original sample, and 250 to 500 fragments measured, the number varying according to the degree of variation found.

(*iv*) *Calculations.*

The quantities and proportions in Table 3 were computed from the analytical figures in Tables 1 and 2, assuming skin area as 100 sq. cm., and fibre length as 10 cm.

The basic figure for dry weight of wool substance per unit area (100 sq. cm.) per unit fibre length (10 cm.) was calculated from the well-known formula:—

Column (1) $W = (L.a.d)n.S$,

where W = dry weight of wool substance,

L = 10 cm. (assumed),

a = mean area of fibre cross-section, i.e., $\left(\frac{f}{2}\right)^2 \times 3{\cdot}14$ (determined, Table 1),

d = specific gravity of wool keratin, i.e., 1·3 (approximately constant),

n = mean number of fibres per sq. cm. of skin surface (determined, Table 1),

S = 100 sq. cm. (assumed).

Column (2) $= \frac{(1) \times \text{Wax index in g.}}{100}$ (determined, Table 2).

Column (3) $= \frac{(1) \times \text{Suint index in g.}}{100}$ (determined, Table 2).

Column (4) = Total of (1) + (2) + (3).

Column (5) $= \frac{(1)}{(4)} \times 100.$

Column (6) $= \frac{(2)}{(4)} \times 100.$

Column (7) $= \frac{(3)}{(4)} \times 100.$

In making these calculations, the assumptions of unit area and unit length are valid, since accurate comparisons are impossible without standard values for these dimensions.

3. Discussion.

These analyses of the raw fleece, though limited in number, cover the known range of variations for each character in the Australian Merino fairly well. This applies more particularly to the values presented for yield, fibre thickness, density of total fibre population, density of primary fibres (and hence of "sweat" glands) and the percentage of primary fibres. Less is known of the range in wax and suint production, but the degree of variation in the amounts of these constituents is probably of a similar order to that of the better known characters.

TABLE 2.—DATA DERIVED FROM CHEMICAL ANALYSIS OF FLEECE SAMPLES.

Sheep No.	Yield of clean dry wool as per cent. of raw dry fleece.	Yield of clean dry wool as per cent. of raw dry fleece (minus dirt).	Index figures for non-wool constituents (dry wool = 100).		
			Wax.	Suint.	Dirt.
1	24·0	30·6	167·5	59 9	85 5
2	35·5	43·0	114·2	17·0	52·9
3	45·5	54·7	72·6	10 5	36 6
4	51·0	54·7	46·0	36 5	13·1
5	58·5	66·5	41·5	8·9	20·8
6	62·2	68·5	31·7	14·5	14·6
7	62·8	65·2	45·0	8·4	5·7
8	70·5	72·5	29·5	8·6	3·7
9	75·0	76·5	24·2	6 6	2 4

TABLE 3.—VALUES COMPUTED FROM HISTOLOGICAL AND CHEMICAL DATA.

Sheep No.	Weight of raw dry fleece constituents (dirt-free) per 100 cm.² of skin (assumed fibre length = 10 cm.).				Physiological fleece constituents.		
	(1) Wool. (g.)	(2) Wax. (g.)	(3) Suint. (g.)	(4) Total. (g.)	(5) Wool. %	(6) Wax. %	(7) Suint. %
1	10·10	16·90	6·05	33·05	30·6	52·2	17·2
2	9·00	10·28	1·53	20·81	43·0	48·4	8·6
3	18·70	13·59	1·97	34·26	54·7	39·6	5·7
4	18·23	8·38	6·65	33·26	54·7	25·2	20·1
5	36·80	15·28	3·28	55·36	66·5	27·6	5·9
6	31·78	10·07	4·61	46·46	68·5	22·2	9·3
7	46·60	20·95	3·91	71·46	65·2	29·3	5·5
8	67·30	19·85	5·79	92·94	72·5	21·4	6·1
9	67·00	16·20	4·42	87·62	76·5	18·5	5·0

The interest of these analyses lies in such comparisons, for example, as that between Sheep Nos. 3 and 4, whose fleeces, when adventitious dirt was eliminated, showed exactly the same percentage yield of clean dry wool. The two animals, on further analysis, are, however, very different. The fleece of Sheep No. 3 is finer, denser, has more wax and less suint than Sheep No. 4 which, on the other hand, has a skin growing a higher proportion of primary fibres but fewer "sweat" glands per unit area than Sheep No. 3. Another comparison is possible between Sheep Nos. 1 and 4, each producing very nearly the same total amount of raw dry fleece (dirt-free). Sheep No. 4, however, produced 85 per cent. more wool but 50 per cent. less wax than Sheep No. 1. The importance of density of fibre population is clearly shown in the comparison between Sheep Nos. 7 and 8, in which Sheep No. 8 produced nearly 45 per cent. more wool than No. 7, due to that factor alone. The part played by fibre thickness in wool production is emphasized in the comparison between Sheep Nos. 3 and 9, both animals being

approximately equal in fibre population density. Sheep No. 9, with nearly 1·9 times the fibre "diameter" of No. 3, produces 3·6 times the amount of wool substance.

Another point to be noted is the absence of any direct relation between the number of "sweat" glands alone, and the amount of suint as determined by the chemical methods used. For example, Sheep No. 6, with 320 "sweat" glands per sq. cm., produced 4·61 g. of suint per unit area, while Sheep No. 3, with 556 glands per sq. cm., produced only 1·97 g. The degree of activity of the glands which in this case may have been influenced by the plane of nutrition must be considered as well as numbers.

Differences in the relative numbers of primary and secondary fibres to be found among Merinos is well shown in Table 1, where the values for the percentage of primary fibres in the population range from 3·4 to 20·9.

The relation between mean fibre thickness and the density of the fibre population is expressed by the density index (Table 1), which indicates the relative compactness of fibre growth. By this method of expressing fleece "density" it is clear that there is an extensive range among these few animals (0·69 to 5·18).

Other comparisons can be made with the data presented, but from what has been said it should be sufficiently clear that in biological observations on the natural fleece, a combination of histological and chemical methods has much to commend it. One of the principal advantages of this dual approach to fleece analysis for certain types of comparison is its avoidance of the difficulties of accurately defining unit area of skin and the elimination of length variation due to varying rates and periods of growth. There are occasions, of course, on which rate of growth in fibre length is required. In fact, in the present series it is an important though undetermined difference between the three main groups of sheep. In Group 1, 10 cm. is approximately 12 months' growth, but only about 10 months' growth for Group 2, and about 8 months' growth for Group 3. Thus, if period of growth were taken into consideration, the wool production figures in Table 3 would need to be multiplied by appropriate factors (e.g., 1, 1·2, and 1·5) for relative rates of growth in fibre length.

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Investigations on the Treatment of Solid Timber with Boric Acid to Render it Immune from the Attack of the Powder Post Borer (*Lyctus brunneus* Stephens).

1.—Laboratory and Preliminary Investigations.

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Summary.

The possibility of treating boards of Lyctus-susceptible timber by diffusion treatments with hot boric acid solutions has been investigated. Three timber species have been studied and schedules have been developed to render their normally susceptible wood completely immune to Lyctus attack up to a depth of 1½ inches. Treated boards up to a thickness of 3 inches can thus be sawn or dressed without fear of subsequent attack. Methods are also given for the chemical control of the treatment.

1. Introduction.

Certain Australian commercial timbers are characterized by deep bands of sapwood and intermediate wood. Red tulip oak (*Tarrietia argyrodendron*, var. *peralata*) (1), yellow carabeen (*Sloanea woollsii*), and white birch (*Schizomeria ovata*) are three important timbers which show this feature. In these three timbers, this part of the log usually contains relatively large amounts of starch which renders it very susceptible to the attack of the Lyctus borer. The Lyctus borer can only attack sapwood when it contains sufficient starch.

In the majority of timbers the small depth of sapwood present does not make Lyctus attack a very serious factor, except in rotary cut veneers. With the three timbers mentioned, however, it is quite possible to obtain wide boards consisting wholly of Lyctus-susceptible sapwood and intermediate wood. Such boards cannot be used with satisfaction, as it is certain that in a short space of time they will be attacked and destroyed by Lyctus. It is obviously necessary to develop methods of treating susceptible timber to avoid this wastage, which is a serious hindrance to the successful utilization of a number of otherwise valuable hardwoods.

Previous investigations of the Division of Forest Products (2) have shown that concentrations of boric acid in timber as low as 0·14 per cent. (based on the air-dry weight of wood) will completely prevent the attack of the Lyctus borer, and that lower concentrations have a definite retarding effect upon larval growth and activity. Methods for introducing the requisite amount of boric acid into susceptible veneers by diffusion treatments have been developed (2) and are being used with excellent results in a large number of commercial treatment plants.

In treatment by diffusion the green timber is immersed in a hot solution of boric acid for a given time. The temperature of the

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solution is usually kept just under the boiling point, so as to obviate excessive evaporation and to obtain the maximum rate of diffusion. This method of treatment has certain advantages over the treatment of dry timber with aqueous solutions. Only one drying is required instead of two with the other method. There is also good evidence that the results of diffusion treatments show less irregularities between different species of timbers. Certain timbers in the dry condition cannot be impregnated with aqueous solutions, even under pressure, but movement of solution through the wood by diffusion seems to be possible with some of these timbers.

The object of this investigation was to determine the conditions required to impregnate with boric acid boards of intermediate wood and sapwood of the three species named above, using the diffusion process. Sufficient boric acid should be introduced to render the whole of the wood immune to Lyctus attack. The process is analogous to the veneer treatments, but more severe schedules are necessary to provide the required depth of penetration.

2. Laboratory Investigations.

The first experiments were carried out with red tulip oak in the following manner:—A freshly cut green board of sapwood and intermediate wood of this timber measuring 48 in. x 5 in. x 3 in., was cut into 24 blocks each measuring 2 in. x 5 in. x 3 in. The end grain faces of each block were thickly coated with a cellulose ester adhesive, which forms a coating which is impermeable to water, and would thus prevent diffusion from the end grain surface. Diffusion along the grain is more rapid than across it, and though it is of little importance in long boards, it would seriously affect the results in small test blocks. Care was taken to ensure that the blocks remained green until they were ready for treatment.

The blocks were then immersed for varying periods in solutions of boric acid, maintained at boiling point. The solution concentrations were 2, 4, 8, and 16 per cent. by weight. Times of treatment were ½, 1, 2, 4, 8, and 16 hours. One block was treated by each combination of concentration and time, making 24 treatments in all. After removal of the blocks from the solution they were washed down to remove the excess surface boric acid and stacked out to season. The solutions above 4 per cent. are greater than saturated at room temperature and change to a semi-solid mass of crystals on cooling.

Determination of Penetrations and Absorptions.

The penetration of boric acid was determined by analysis of samples taken at increasing distances from the surface. The blocks were dressed on all faces before sampling, to remove the cellulose ester coating and excess boric acid on the surface. Successive shells of wood of 3/16 in. thickness were taken from each block, reduced to about 6-8 mesh, and analysis samples taken representing each shell. The samples were analysed for boric acid in a series from the outer shell of each block inwards, until the boric acid content fell to the limiting value for Lyctus prevention. This was assumed to be the limit of effective boric acid penetration in the particular block. With long treatments and concentrated solutions, complete penetration was obtained. Whenever this occurred, five 3/16 in. shells and the wood remaining at the centre

were taken for analysis. The results are expressed as a percentage of boric acid based on the moisture-free weight of the wood, and are given in detail in Table 1.

TABLE 1.—SUMMARY OF RESULTS: BORIC ACID DIFFUSION TREATMENTS. RED TULIP OAK BLOCKS.

Schedule of Treatment.		Percentage of boric acid present in samples taken at distances indicated (based on moisture-free weight of wood).					
Time.	Concentration.	0–$\frac{1}{16}$".	$\frac{1}{16}$"–$\frac{1}{8}$".	$\frac{1}{8}$"–$\frac{3}{16}$".	$\frac{3}{16}$"–$\frac{1}{4}$".	$\frac{1}{4}$"–$\frac{5}{16}$".	$\frac{5}{16}$"–Centre.
hrs.	%	%	%	%	%	%	%
16	16	5·49	1·43	0·99	0·63	0·63	0·65
16	8	3·48	1·05	0·46	0·30	0·24	0·27
16	4	1·85	0·61	0·38	0·30	0·34	0·35
16	2	0·86	0·22	0·05	..	..	..
8	16	4·37	1·14	0·62	0·53	0·24	0·49
8	8	2·00	0·49	0·21	0·17	..	..
8	4	1·26	0·25	0·07	..	..	..
8	2	0·85	0·15	..	..	..	..
4	16	2·00	0·38	0·14	..	..	..
4	8	1·45	0·40	0·05	..	..	..
4	4	0·99	0·12	..	..	..	..
4	2	0·51	0·03	..	..	..	..
2	16	1·62	0·19	..	..	..	..
2	8	1·30	0·09	..	..	..	..
2	4	0·85	0·12	..	..	..	..
2	2	0·40	0·00	..	..	..	..
1	16	1·15	0·22	..	..	..	..
1	8	0·61	0·06	..	..	..	..
1	4	0·43	0·00	..	..	..	..
1	2	0·21	..	..	..	..	..
$\frac{1}{2}$	16	1·03	0.11	..	..	..	..
$\frac{1}{2}$	8	0·50	..	..	..	..	..
$\frac{1}{2}$	4	0·33	..	..	..	..	..
$\frac{1}{2}$	2	0·09	..	..	..	..	..

Fig. 1 shows the results for the 8 and 16 hour treatments presented graphically. In preparing these graphs the analysis result for each shell was assumed to be the concentration at the mid-point of the shells. This assumption is not strictly exact, but it serves to illustrate the changes in concentration through each block.

On consideration of the results from the red tulip oak samples, the experiments with yellow carabeen and white birch were commenced. The red tulip oak results showed the uselessness of the short-time, low-concentration treatments, when deep penetration is required, and these were accordingly eliminated. In the light of the experience gained with red tulip oak, a slightly different method of treatment was used. Three flitches of the green sapwood of each timber were obtained from three separate logs. Three billets measuring 12 in. x 2 in. x 2 in. were cut from each flitch. The billets were then coated on each end with the cellulose ester adhesive.

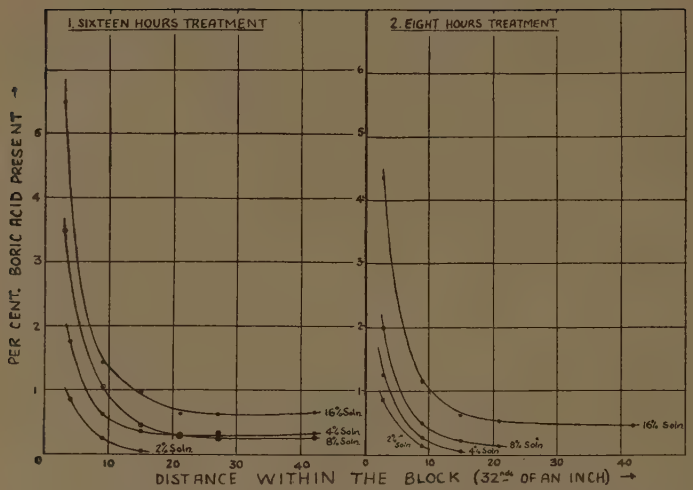

FIG. 1.—Graphs showing the relation between depth of penetration and concentration of boric acid, for the 8 and 16 hour treatments on red tulip oak.

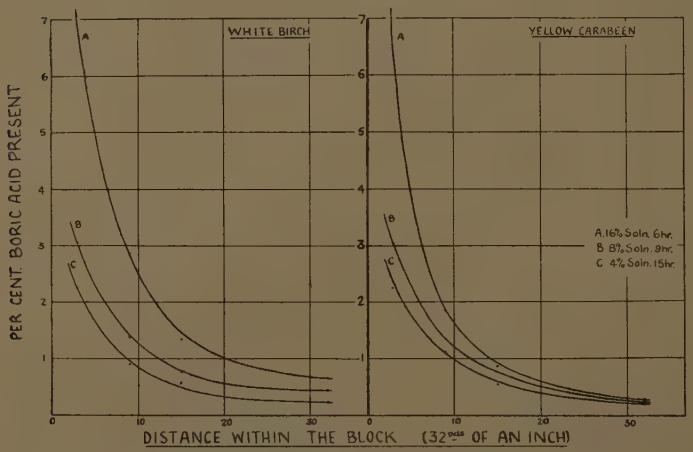

FIG. 2.—Graphs showing the relation between depth of penetration and concentration of boric acid, for the three treatments of white birch and yellow carabeen.

Three treatment schedules were used, and one billet from each flitch was treated under each schedule. Twelve-inch billets were used instead of short blocks in order to eliminate completely any end effects. Only the central 2-inch section of each billet was used for analysis. Billets

from three different trees were treated to obtain an indication of the variation existing within a species. The schedules used were—

(1) 4 per cent. boric acid solution for 15 hours at boiling point.

(2) 8 per cent. boric acid solution for 9 hours at boiling point.

(3) 16 per cent. boric acid solution for 6 hours at boiling point.

The green specimens were immersed in the boiling solutions for the specified times. It was estimated that these schedules, from a consideration of the red tulip oak results, would give just enough boric acid, at the centre of the billets, for complete Lyctus prevention. The penetration of boric acid was determined, as before, on the 2-inch section cut from the centre of the billets. Three 3/16 in. shells and the centre piece remaining were taken for analysis, the results of which are given in Table 2. The average results for the three logs are graphed in Fig. 2.

3. Discussion of Results.

(a) Red Tulip Oak.

The results show that it is possible to introduce sufficient boric acid to prevent Lyctus attack into the timber to a depth of 1½ inches. This necessitated a fairly prolonged treatment time and the use of high concentrations. All the 16-hour treatments, except that with 2 per cent. solution, and one of the 8-hour treatments, gave more than sufficient boric acid right through the block.

The shorter schedules also show themselves to be quite suitable for certain purposes, the 4-hour treatments giving protection for a depth of about ⅝ in. There seems to be in all cases enough boric acid in the first layer of each block, but in the ½-hour treatments the boric acid is probably all in the first ¼ in. These short treatments, however, would be valuable where protection for a limited period is required, and where the timber is cut to the right size before treatment.

In all cases the boric acid concentration in the first layer is much greater than that of the second and third. This is illustrated well in the graphs by the initial steep slopes of the curves. It will be seen that it is necessary to have a large excess of boric acid in the outer layers of the timber in order to guarantee protection for the interior.

(b) Yellow Carabeen and White Birch.

The graphs and results show that there is very little difference between the behaviour of these timbers, and for practical purposes they may be considered together. With white birch it appears that slightly higher quantities of boric acid can be obtained at the centre, but the concentrations at this point in the yellow carabeen samples were exactly as predicted.* It is seen that these two timbers absorb more boric acid than the red tulip oak and seem to be easier to penetrate. As would be expected, greater concentrations of boric acid in the first layer are obtained with the more concentrated solutions, but the high boric acid content is not carried far into the timber because of the short times used with the stronger solutions.

* The diffusion treatment of veneer (2) showed that the percentage boric acid absorbed was inversely proportional to the density of the timber, i.e., the weight of boric acid taken up by a given volume of timber is approximately constant for all timbers. The schedules for treatment of yellow carabeen and white birch were estimated on this basis by comparison with the red tulip oak results.

TABLE 2.—SUMMARY OF RESULTS: BORIC ACID DIFFUSION TREATMENTS OF WHITE BIRCH AND YELLOW CARABEEN.

Schedule of Treatment.	Timber.	Log No.	Percentage of boric acid present in samples taken at distances indicated (based on moisture-free weight of wood).			
			0–$\frac{1}{8}$". (A).	$\frac{1}{8}$"–$\frac{1}{2}$". (B).	$\frac{1}{2}$"–$\frac{5}{8}$". (C).	$\frac{5}{8}$"–Centre.
15 hours 4% solution, at boiling point	White birch	1	2·11	0·71	0·25	0·08
		2	2·18	0·95	0·38	0·13
		3	2·41	1·05	1·11	0·52
		Average	2·23	0·90	0·58	0·24
	Yellow carabeen	1	2·19	0·87	0·39	0·22
		2	1·98	0·74	0·30	0·11
		3	2·82	1·71	0·93	0·32
		Average	2·33	1·11	0·54	0·22
9 hours 8% solution, at boiling point	White birch	1	3·28	1·20	0·41	0·20
		2	2·96	1·31	0·87	0·60
		3	2·87	1·66	1·01	0·58
		Average	3·04	1·39	0·76	0·46
	Yellow carabeen	1	3·33	1·17	0·36	0·11
		2	2·19	1·09	0·52	0·33
		3	3·52	1·73	0·71	0·26
		Average	3·01	1·33	0·53	0·23
6 hours 16% solution, at boiling point	White birch	1	8·87	2·54	1·02	0·30
		2	6·93	4·04	1·61	0·85
		3	5·43	1·96	1·35	0·82
		Average	7·08	2·85	1·33	0·66
	Yellow carabeen	1	6·58	1·30	0·43	0·09
		2	6·64	2·05	1·39	(2·18)*
		3	8·28	2·17	0·82	0·39
		Average	7·17	1·84	0·88	0·24

* Omitted from average.

There is very little variation between the results for the three separate logs in both species, especially in the 15 and 9-hour treatments. The 16 per cent. 6-hour treatment, however, gives slightly irregular results. The shortness of the treatment would probably be the cause of these erratic results. The longer treatments would provide the necessary time to smooth out the irregularities of diffusion which would possibly occur in the first few hours of the treatment, when high boric acid concentration gradients are present at the surface and inside the timber. The concentration of boric acid in any of the layers does not appear to show any direct relation to the concentration of the solution. With the 16 per cent. solution, even though it is only used for six hours, more than twice as much boric acid is absorbed in the first layer than with the 8 per cent. solution for nine hours, whilst with the 15-hour 4 per cent. treatment about two-thirds as much is absorbed as with the 9-hour treatment. The reason for this anomaly is not definitely known.

(c) General Discussion.

With the object of providing data for use in commercial treatments, charts were prepared for red tulip oak and for yellow carabeen and white birch (see Figs. 3 and 4). From these charts the relation between depth of timber rendered immune, time of treatment, and concentration of solution can be obtained. The depth of timber rendered immune is taken as the depth at which there is 0·2 per cent. boric acid (derived from Figs. 1 and 2). The figure 0·2 per cent. has been taken to allow a slight tolerance above the actual figure, 0·14 per cent., in order to provide a safe margin for possible variations in the particular species of timber. In these charts, the extra solution concentrations have been inserted by interpolation, but the charts have been tested over a wide range and have been found to give good results. The errors due to variation within the one species of timber are greater than the differences between actual and predicted results, showing that the charts may be used quite satisfactorily for estimating treatment schedules, according to the depth of protection required. With the very high concentrations of boric acid the predictions from the chart may be somewhat inaccurate, but concentrated solutions have other undesirable characteristics, and it is inadvisable to use solutions above 16 per cent. When concentrated solutions are used, control of the treatment becomes difficult and a large wastage of boric acid cannot be avoided.

4. Commercial Application of the Treatment.

(a) Cost of Treatment.

There are two factors to be considered under this heading. Firstly, the cost of chemical consumed, and secondly the cost of operating the plant. For a given timber, treatment to a specified depth can be carried out by a large number of different schedules as shown on the charts (Figs. 3 and 4). Short time, high concentration schedules require a large amount of boric acid in the outer layers, as indicated in Fig. 2, to give the required penetration. In this case, the value of the boric acid used can be shown to be the major factor. Similarly, when long time, low concentration treatments are used the boric acid is more evenly distributed through the timber and less is required, and the major cost factor per charge is that of the plant operation. Thus, for

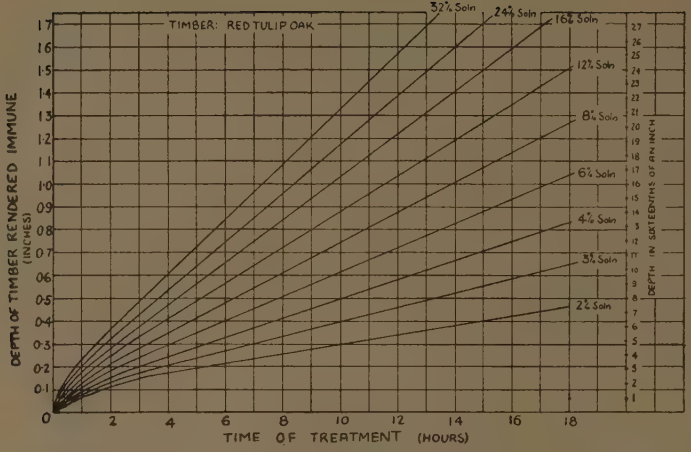

FIG. 3.—Chart for computing schedules for treatment of red tulip oak boards.

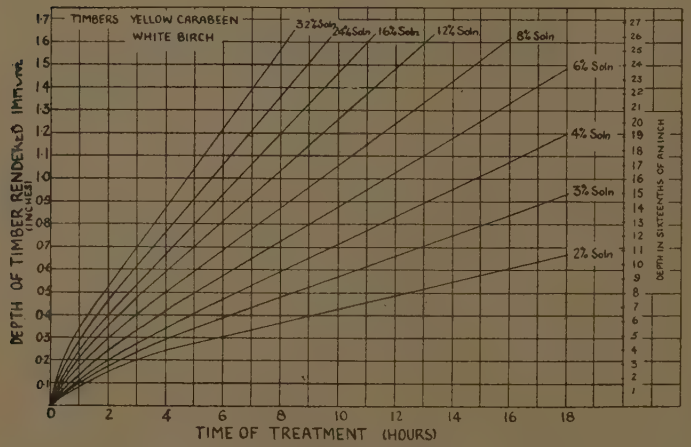

FIG. 4.—Chart for computing schedules for yellow carabeen and white birch. These two timbers have been grouped together because they have almost the same treating properties.

a given treatment when boric acid costs are high the operating costs are low and vice versa. It is obvious that between the two extremes there is an optimum treating schedule for which the total cost is a minimum. This optimum will depend on the relative values of the price of boric acid and the hourly operating cost.

When the depth of penetration is specified for a given timber, the time of treatment is sufficient to specify the schedule, as the solution concentration required is automatically fixed by Figs. 3 or 4. Thus the optimum treating schedule can be obtained by investigating the

variation of total cost with treatment time, using in each case the requisite solution strength for the specified penetration. This is illustrated in Fig. 5 where the cost is plotted against time, in the treatment of white birch to 1 inch in depth. The costs are only relative values, but they show that it is advantageous to select treatment schedules carefully with an accurate knowledge of the two cost factors.

In the case illustrated the most economical time is 9½ hours, and Fig. 4 shows that a solution concentration of 8 per cent. should be used for 1-in. penetration. Accurate data are not yet available to enable the treatment costs to be calculated exactly, but it seems that the total cost will be such that the process will be economically possible. It must be emphasized that the optimum treatment schedule referred to above will vary with the depth of penetration required and the species of timber treated, as well as with variations in the two cost factors. Increase in the price of boric acid will displace the minimum towards longer times, whilst increased plant operation costs will have the reverse effect. The economic aspect of the treatment will be discussed in full detail in Part 2 of this paper, which will be available at a later date.

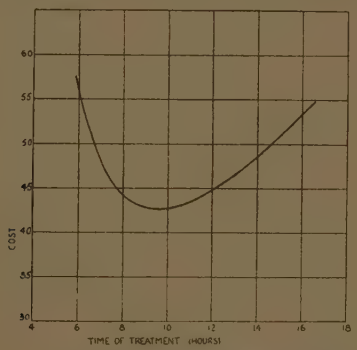

Fig. 5.—Showing the relation between time of treatment of white birch to a depth of 1 inch, and total cost (costs are only relative, as exact figures are not yet available).

(*b*) *Equipment and Plant Required.*

Part 2 will also include the results of investigations which are now being carried out to determine the most suitable materials for the construction of the treating tank, and other equipment. It is also hoped to include the results of pilot treatments in an experimental treating vat.

The following points are at the present time outstanding: A wooden vat, suitably constructed, seems to be the best type of treating tank, under the present circumstances. Copper is also a suitable material for constructing the tank, but it is at present so scarce that its use is probably impossible. Concrete is readily attacked by boric acid, and is wholly unsuitable. Acid-proof and ordinary bricks have been tried, but difficulties in obtaining a suitable mortar, and the high cost of acid-proof bricks, render these unsuitable.

(c) Chemical Control of Treatment.

Large changes in concentration of the treating solution are liable to take place during the operation of a treating plant. These changes will be due mainly to evaporation of water and removal of boric acid by the timber. A method of checking the strength of solution from time to time is obviously necessary. The method, moreover, should be simple and rapid, and if possible capable of being used by a person with no special chemical training. The solution cannot be directly titrated with alkali, because the extracts from the timber cause a dark colouration, interfering with indicators, but a method of preparing a sample of solution in a suitable state for titration has been developed, and details of it are given in Appendix I.(*a*). This method has been used satisfactorily in checking the veneer-treating solutions of 1·25 per cent. strength.

The high concentration of the solutions used in the treatment of solid timber suggested an alternative method of checking the solution strength. This method was investigated and successful results were obtained. A saturated solution of boric acid at room temperature contains about 4 per cent. by weight. The majority of the treating solutions will be more concentrated than this, but as they are always used at elevated temperatures and the solubility at the boiling point is about 30 per cent., there is no difficulty in preparing the solutions. The method of determining the strength of these solutions is to measure the temperature at which the first crystals appear, while the solution is cooling. The solution strength will then be the saturation value at this temperature, read off from a solubility curve or table.

The solubility of boric acid was investigated over the range from room temperature to boiling point by preparing solutions of strengths from 5 to 27 per cent. at 2 per cent. intervals, and measuring the temperature of crystallization of each solution. Figure 6 shows the solubility curve obtained. The presence of wood extractives was found to have no effect on this property. The presence of the first crystals can easily be detected, especially in solutions which have been deeply coloured with wood extractives where the crystals appear as golden

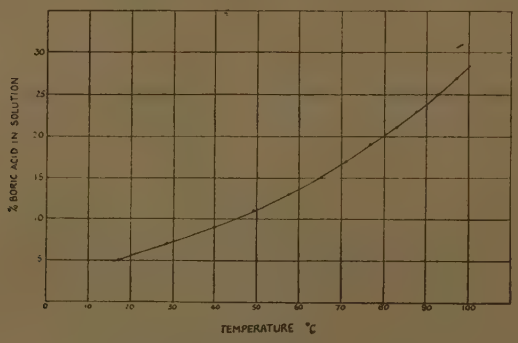

Fig. 6.—Solubility/Temperature curve for boric acid in water.

flakes, when observed with the light behind the operator. The temperature can be measured without difficulty to the nearest degree Fahrenheit. No serious error can occur in detecting the formation of the first crystals, because before the temperature has fallen another half degree the solution is filled with a mass of flaky crystals and later becomes semi-solid.

Table 3 shows the solution strengths corresponding to the crystallization temperature for temperatures from 59° to 212°F., at one degree intervals. It is easy to read the temperature of crystallization to the nearest degree, and this gives the result correct to 0·1 per cent. at the lower concentrations, but increasing to 0·2 and 0·3 per cent. at the higher concentrations. The fractional error over the whole range is almost constant and is well within the requirements. Full details for carrying out the determination are given in Appendix I. (*b*).

TABLE 3.—TABLE FOR CONVERTING TEMP. (°F.) OF CRYSTALLIZATION TO PER CENT. BORIC ACID IN SOLUTION.

Temp.	Boric Acid in Solution.	Temp.	Boric Acid in Solution.	Temp.	Boric Acid in Solution.	Temp.	Boric Acid in Solution.
°F.	%	°F.	%	°F.	%	°F.	%
59	4·7	98	8·4	137	13·1	176	20·0
60	4·8	99	8·5	138	13·2	177	20·2
61	4·9	100	8·6	139	13·4	178	20·4
62	4·9	101	8·7	140	13·5	179	20·6
63	5·0	102	8·8	141	13·7	180	20·8
64	5·1	103	8·9	142	13·8	181	21·0
65	5·2	104	9·0	143	14·0	182	21·2
66	5·3	105	9·1	144	14·1	183	21·4
67	5·4	106	9·2	145	14·3	184	21·6
68	5·5	107	9·3	146	14·5	185	21·8
69	5·6	108	9·4	147	14·7	186	22·0
70	5·7	109	9·5	148	14·8	187	22·2
71	5·8	110	9·6	149	15·0	188	22·5
72	5·9	111	9·7	150	15·2	189	22·7
73	6·0	112	9·8	151	15·4	190	22·9
74	6·1	113	10·0	152	15·5	191	23·1
75	6·2	114	10·1	153	15·7	192	23·3
76	6·3	115	10·2	154	15·9	193	23·5
77	6·4	116	10·3	155	16·1	194	23·7
78	6·5	117	10·5	156	16·3	195	24·0
79	6·6	118	10·6	157	16·5	196	24·2
80	6·7	119	10·7	158	16·6	197	24·5
81	6·8	120	10·8	159	16·8	198	24·7
82	6·9	121	10·9	160	17·0	199	25·0
83	7·0	122	11·0	161	17·2	200	25·2
84	7·0	123	11·2	162	17·3	201	25·5
85	7·1	124	11·3	163	17·5	202	25·7
86	7·2	125	11·4	164	17·7	203	26·0
87	7·3	126	11·6	165	17·9	204	26·2
88	7·4	127	11·7	166	18·1	205	26·5
89	7·5	128	11·8	167	18·3	206	26·7
90	7·6	129	12·0	168	18·5	207	27·0
91	7·7	130	12·1	169	18·7	208	27·2
92	7·8	131	12·2	170	18·9	209	27·5
93	7·9	132	12·4	171	19·1	210	27·7
94	8·0	133	12·5	172	19·3	211	28·0
95	8·1	134	12·7	173	19·5	212	28·3
96	8·2	135	12·8	174	19·6		
97	8·3	136	13·0	175	19·8		

This method cannot be applied if materials that are attacked by boric acid are used for constructing the treatment tank. Such materials include concrete, ordinary mortar for cementing the bricks, &c. These materials rapidly produce calcium borate, and small quantities of aluminium borate and magnesium borate, the presence of which causes changes in solubility, and even precipitation of boric acid as calcium borate. The solution strength should be checked at least once a day, during the operation of the plant, and the necessary alterations made immediately. If this is not done there can be no guarantee of the effectiveness of the treatment.

Representative samples of the treated timber should also be tested as a check on the treatment schedules. One or two boards from a batch should be taken every few days and analysed by the method given in Appendix II. (*a*). The method is simple and can be carried out by any competent analyst. The sample should consist of a block cut from the centre of the board and this should be tested in a manner according to the depth of penetration specified. The turmeric test (3) can be applied as a qualitative test for the penetration of boric acid. It is extremely sensitive and is practically specific for boric acid. Two methods of applying this test are given in Appendix II. (*b*).

5. Conclusion.

It is hoped that the results of this investigation will be of assistance in solving the serious problem of the disposal of these Lyctus-susceptible timbers. The treatment with boric acid will render the timber permanently immune from Lyctus attack in sheltered positions. Boric acid, being soluble in water, is not recommended for treating timber for use in exposed situations where rain will leach the preservative out.

No claim is made for boric acid as a general preservative, as it has so far only been tested against *Lyctus brunneus,* but there is a possibility, as it is so toxic to Lyctus, that it will prevent other insect attack. However, surface stains and moulds have been observed growing on moist boric-acid treated timber.

6. Acknowledgments.

The author wishes to thank members of the staff of the Division of Forest Products who rendered assistance in this investigation. Special thanks are due to Mr. S. F. Rust who supervised the latter part of the work, and to Mr. J. E. Cummins, under whose direction the investigation was initiated.

7. References.

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(2) Cummins, J. E.—The Preservation of Timber against the Attacks of the Powder Post Borer (*Lyctus brunneus* Stephens) by Impregnation with Boric Acid. *J. Coun. Sci. Ind. Res.* (Aust.), 12: 30-49 (1939).

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Appendix I.

Determination of the Concentration of Boric Acid Solutions.

(*a*) *Titration Method.*

Aliquots of the solution are pipetted into platinum dishes and excess caustic soda solution added. The solution is evaporated to dryness on an Argand burner or a water bath, and the residue is ignited over a Meker burner until all the organic material is removed. The residue is then dissolved in enough dilute hydrochloric acid to just neutralize the caustic soda. The solution is then transferred to a 50 or 100 ml. standard flask and made to volume. To 25 ml. aliquots of this solution in 250 ml. conical flasks are added 3 drops of methyl orange and then 15 per cent. caustic soda until the solution is just alkaline; 10 per cent. hydrochloric acid is then added until the reaction is just acid to methyl orange.

The solution should then be boiled under air reflux for about 10 minutes to remove the carbon dioxide, making sure that no steam issues from the top of the condenser. After cooling, the solution is adjusted to the methyl orange end point with standard carbonate-free caustic soda (N/20 or N/10 according to strength of boric acid solution). Excess glycerol is added (about 40 ml.), together with 1 ml. of 1 per cent. phenolphthalein, and the solution titrated to the phenolphthalein end point, with the (N/10 or N/20) carbonate-free caustic soda. The boric acid is equivalent to the volume of caustic used, after deducting a blank due to the acidity of the glycerol. Boric acid acts as a monobasic acid, under these conditions—

$$H_3BO_3 + NaOH \longrightarrow NaBO_2 + 2H_2O$$

(*b*) *Crystallization Method.*

A 100 ml. sample of the hot solution is taken in a warmed 250 ml. flask. The flask should be fitted with a small air condenser if the solution is very concentrated. The thermometer may be placed with its bulb in the solution, and stem in the condenser tube. The solution should then be cooled rapidly by immersion in cold water, and an approximate value of the crystallization temperature obtained. The solution is re-heated until all the boric acid is dissolved, and then cooled by immersion in cold water, with frequent shaking to prevent local cooling and crystallization, until the temperature is about 5°F. above the crystallization temperature. The solution is then allowed to cool in the air and is observed with suitable lighting behind the operator, until the first crystals are seen, and the temperature is then read. The whole procedure should be repeated as a check on the result. The per cent. boric acid in the solution can then be read directly from Table 3.

A Fahrenheit thermometer is used in the determination, because its closer scale eliminates the reading of fractions of degrees, to get accurate results. When testing solutions of concentration greater than 16 per cent. it might be advisable to dilute the solution accurately to about 10 or 12 per cent. With solutions above 16 per cent. the temperature falls so rapidly in the region of the crystallization temperature that it is difficult to make an accurate observation. In this case a predetermined quantity of water should be added to a weighted quantity of solution to make the solution approximately 12 per cent. The weights need be taken only to the nearest ½ gramme. The strength of the approximately 12 per cent. solution should then be determind by the method described above, and the concentration of the initial solution calculated by—

$$S = P\left(1 + \frac{m}{M}\right)$$

where—

P = strength of the diluted solution.
m = weight of water added.
M = weight of solution taken.
S = strength of the initial solution.

Appendix II.

Determination of Boric Acid and Borates in Timber.

(*a*) *Quantitative Analysis.*

A 5·00 g. sample of ground-up wood is mixed with 2·5 g. of lime-eschka mixture* and placed in a platinum dish. The sample is covered evenly with a further 3 g. of lime-eschka. The sample is gently ignited over a medium burner flame until spontaneous flaming in the sample ceases; the ignition is then continued over a Meker burner until most of the carbon is removed and the mixture is a light-grey colour. Care should be taken not to fuse or sinter the mixture during the ignition. The ignition should not take longer than 20–25 minutes.

The mixture is then broken up to fine powder in the dish using a small pestle, and the powder is transferred to a 400 ml. beaker. If the ignition is correctly carried out the mixture will come away cleanly from the platinum dish and no lumps or carbon or fused mixture will remain. The dish is then washed out with a few ml. of dilute hydrochloric acid, and the washings added to the beaker. About 10 ml. of water and then sufficient conc. hydrochloric acid is added to dissolve the mixture; from 15 to 20 ml. of acid should be sufficient, and there should be a slight excess. The beaker should be covered with a watch glass during this operation to prevent loss by spattering.

To the solution in the beaker is now added a few drops of phenolphthalein, followed by sufficient 15 per cent. caustic soda, added dropwise, to make the solution just alkaline. The contents of the beaker are then washed into a 100 ml. standard flask and made to volume. The solution is filtered through a dry paper into a dry beaker. Aliquot samples (25 ml.) of the filtrate are pipetted into 250 ml. conical flasks and treated as follows:—10 per cent. hydrochloric acid solution is added dropwise until the phenolphthalein colour is discharged, then a few drops of methyl orange are added and the addition of acid is continued until the solution is just acid to this indicator. The solution is boiled gently under reflux for about 10 minutes to remove the carbon dioxide from solution, taking care that no large amount of steam issues from the top of the condenser. When the solution is cool it is then adjusted to the methyl orange end point by means of N/20 caustic soda solution. Excess glycerol (about 40 ml.) and 1 ml. of phenolphthalein are added to the solution, and it is then titrated to the phenolphthalein end point with standard N/20 carbonate-free caustic soda solution. The end point is different from the usual phenolphthalein end point in the fact that it occurs only as a faint orange colour, which is easily missed if care is not taken. At the end point, the solution changes in colour from the yellow of the alkaline methyl orange, to a colour closely resembling the neutral orange colour of this indicator; the addition of a further drop of caustic soda produces a very faint pink colour. Experience and tests with known quantities have shown that the occurrence of the orange colour is the true end point of the reaction, but it is very hard to detect. However, the addition of the extra drop after reading the burette, easily verifies the judgment of the true end point.

A blank due to the acidity of the glycerol must be deducted from the titre. The acidity of the glycerol is determined by titrating measured quantities with equal volumes of water, to the phenolphthalein end point with the N/20 caustic soda.

The boric acid acts as a monobasic acid in the presence of glycerol, therefore

$$1 \text{ ml. of N/10 NaOH} \equiv 0{\cdot}00618 \text{ g. } H_3BO_3$$

(*b*) *Qualitative Analysis using Turmeric.*

A few small chips are extracted with 1 to 2 ml. alcohol by warming gently in a porcelain dish for a few minutes. The alcohol is decanted off into another dish and a few drops of acetic acid and alcoholic tincture of turmeric added.

* Lime-eschka mixture consists of a finely ground mixture of 3 parts of calcium oxide to one part of anhydrous sodium carbonate.

The solution is then diluted slightly with water and evaporated to dryness on the water bath. A trace of boric acid will produce a definite red stain in the dish. The test must be confirmed by addition of caustic soda when a temporary blue-black colour is produced by the boric acid stain.

Turmeric paper may be used also, but it is not so precise and easy to apply. A piece of turmeric paper, moistened with dilute hydrochloric acid, is placed in contact with a freshly cut surface of the timber. The paper is then dried very gently. Boric acid stains the paper red.

Pasture Research by the Division of Plant Industry.

Work of the Agrostology Section.*

The work of the Agrostology Section is directed to the improvement of pastures and the control of noxious weeds. Pasture experiments are in progress at Canberra, at Griffith in the Murrumbidgee Irrigation Area, at "Gilruth Plains," Cunnamulla, Queensland, and in Western Australia. The main weeds work at present in progress is on hoary cress in Victoria, on galvanized burr in Southern Queensland, and on St. John's wort.

Improvement of Pastures.

The pasture experiments will be dealt with first, citing the main objectives of the work and referring briefly to the information being obtained. It will be appreciated that these pasture experiments are either in their first or second year, and conclusions cannot be drawn for another two or three seasons.

Canberra.

The Southern and Central Tablelands and slopes of New South Wales are characterized by a relatively uniform distribution of the rainfall throughout the twelve months of the year. Long dry periods are experienced at any period of the year and dry winters are common. Thus in Canberra, both in 1940 and 1941, mid-season subterranean clover failed to set seed satisfactorily.

Our trials in Canberra are directed, firstly, to seeking for species and strains that will persist and yield satisfactorily in these areas of uniformly distributed rainfall, and, secondly, to the development of improved pasture mixtures and of grazing practices.

A range of selected grasses and legumes has been tested in swards during the past three seasons, including a number of pasture species introduced by the Plant Introduction Section. At present, *Phalaris tuberosa*, subterranean clover, and lucerne are the only three satisfactory plants. Of the remaining 50 grass species and 21 legumes tried, the only plants that may prove of value are cocksfoot, *Bromus* spp. (including prairie grass), Wimmera ryegrass, and *Festuca Mairei*—the latter an introduction from Morocco.

Although both lucerne and subterranean clover make good growth, there are many indications that the soils here are deficient in some essential element for legume growth. Several field and pot tests are in progress in an attempt to discover the trouble. The deficiency is akin to that present in certain ironstone soils in South Australia, where the application of wood ash was found to overcome the deficiency. The deficiency is suspected to be due to the lack of a minor element.

* Notes from an address given by Dr. J. Griffiths Davies to a meeting of the full Council, Canberra, November, 1941.

A grazing management trial on a sown pasture of *Phalaris,* lucerne, and subterranean clover is now in its second year. The objective is to compare the effects of continuous grazing and of monthly and bi-monthly rotational grazing on the yield, botanical composition, and chemical composition of the pasture, and on the liveweight, wool production, and internal parasitism of the sheep. The sheep are carried entirely on the pasture and an average of three sheep per acre has been maintained up to the present.

Only in January and February, 1941, has there been a significant difference between the grazing treatments—this period being the only good rain period during the trial. At this stage a marked increase in the percentage of lucerne was recorded in the bi-monthly rotation—20 per cent. of the yield being lucerne as against less than 1 per cent. on the continuously grazed plots. There was also a significantly higher yield on the bi-monthly grazed plots. The liveweight and wool production of the sheep have not been affected by grazing treatment—the average greasy fleece weight in October this year being 12 lb. 13 oz. per head.

Irrigated Pastures at Griffith.

The new irrigation areas developed and in the course of development in the Riverina comprise over 2,000,000 acres, of which between 200,000 and 250,000 acres will have full water rights, on the basis of a water right to each 8 to 10 acres of holding. These areas receive from 14 to 17 inches per annum of natural rainfall, with a slight winter maximum. Two methods of using the irrigation water on pastures are possible:—

(*a*) To apply the whole water right on 10 per cent. of the holding and to grow fully irrigated pastures.

(*b*) To supplement the natural rainfall with autumn and spring waterings, and so to ensure a safe winter growth period over some 30 to 40 per cent. of the holding.

The trials at Griffith are designed to compare the yield per unit of water applied to fully irrigated pastures and to winter-growing pastures. The winter pastures have just completed their first season, and the fully irrigated summer-growing pastures have been sown this spring.

"Gilruth Plains."

The work at Gilruth Plains is the study of the Mitchell grass association and the effect of different intensities of grazing, both on the pastures and on the sheep grazing on them.

Six hundred acres of Mitchell grass plain have been subdivided into 90 plots, and nine grazing treatments are being applied. There are three rates of stocking: one sheep to 2½, one to 5, and one to 7½ acres, representing overstocking, normal stocking, and understocking, respectively. Each of these three rates is combined with continuous grazing, grazing for the six summer months, and for the six winter months.

Records of the yield and composition of the pasture, and of the liveweight and wool yield of the sheep are made every three months. The wool samples are forwarded to the Nutrition Laboratory in Adelaide where the weight, length, and diameter of the wool fibres are measured.

The experiment has been in progress for nine months, and the first year's fleece weights indicate that the rate of stocking affects the wool yield per sheep. Thus the yield of wool per sheep from the understocked treatment was 10 lb. 1 oz., from the normal stocking 9 lb. 15 oz., and from the overstocked treatment 9 lb. 0 oz. It remains to be seen whether these differences will be maintained.

With the breaking of the drought in January, 1941, the opportunity was taken of recording the response of the Mitchell grass association to heavy rains. A short article on this subject appeared in the *Journal* (14 : 253, 1941). The outstanding features were :—

(1) The low yield of 17 cwt. per acre.
(2) The low contribution of Mitchell grass to this yield—only 8 per cent., as compared with 75 per cent. from the annual grasses—mainly Flinders grass and button grass.
(3) The short growing period of only eight or nine weeks from the commencement of the rains until the pastures were drying off.

The low proportion of Mitchell grass is attributed to the preceding drought, but a good establishment of Mitchell grass seedlings was recorded, and it is expected that these will thicken up the existing stand.

Many attempts have been made to conserve hay from Mitchell grass pastures, but the results have not been satisfactory. The yield and quality of the hay seem to be low, and detrimental effects on the stand of Mitchell grass may follow hay cutting. These matters are being studied, but it has been found difficult to produce satisfactory plots of Mitchell grass for the trials. The grass transplants very badly, and seedlings are not fully grown until their third year.

Western Australia.

The main experiments in Western Australia are designed to determine the best grass species for inclusion with subterranean clover on rainfalls between 15 and 25 inches per annum. The results to date have been disappointing, partly because of the serious competition from cape weed in the seeding year. *Phalaris tuberosa,* Wimmera ryegrass, and perennial veldt grass are the only grasses of promise, but it has not been possible to establish satisfactory plots up to the present.

The elimination of cape weed competition is being investigated. Results at New Norcia this season show that sowing of fallow land on the first rains in May—the best practice in South Australia—results in extremely heavy cape weed. Equally dense, but less vigorous stands of the weed were recorded on autumn ploughed land. June seeding, enabling more autumn cultivation to be done, resulted in materially less cape weed, but control was not at all satisfactory. In the coming season further trials are projected in which timing of cultivations and the use of oats as a cover crop will be tested. It may even be necessary to sow the pasture species on stubble ground—though this is against accepted practice especially with *Phalaris tuberosa.*

Detailed studies of perennial veldt grass and of lupins have also been undertaken. The work with perennial veldt grass will not be carried further until satisfactory evidence of its value as a pasture species has been obtained, though the excellent collection of types will be maintained.

Studies on lupins have been seriously affected by a virus disease which interferes with flowering and seed setting. An officer has been in Perth during this season studying the disease and its alternative hosts.

Weeds Control.

St. John's Wort.

Control of St. John's wort on roadsides and waste places can be obtained on application of common salt—a costly and tedious process. On agricultural land this method is impracticable, both on the score of cost and because of the effect of the salt on the soil—that of producing sodium clays. Control by other weedicides is most unsatisfactory.

In experiments initiated by Dr. Currie, and concluded this year, it has been found that on pasture land St. John's wort is very easily controlled and practically eliminated. Excellent results follow the use of subterranean clover with superphosphate, but complete elimination of the weed has been obtained by fallowing, sowing down a mixture of *Phalaris tuberosa* and subterranean clover, and top-dressing annually with superphosphate. In southern New South Wales and north-east Victoria the weed is only present in the cool, better rainfall districts, and the method of controlling by the sowing down of improved pastures is both simple and economic. This weed is also present in the Mudgee district. It is not expected that subterranean clover will be successful here, so that this particular pasture mixture will not be effective.

Hoary Cress.

Hoary cress is the most serious weed of cultivation in Victoria, and is causing serious losses in the Wimmera wheat-growing areas. Two seasons' work with weedicides near Murtoa and at Werribee have shown that hoary cress cannot be controlled satisfactorily with weedicides.

Tests of pasture species and mixtures have been laid down to find out whether pasture mixtures can be devised which will compete successfully with the weed. Lucerne, Wimmera ryegrass, and *Phalaris* would seem to offer the greatest possibilities. Even if excellent pastures can be grown in the Wimmera there will remain, as in the skeleton weed areas of the Riverina, the serious economic problem of changing from the wheat fallow rotation to one in which pasture and grazing stock form an important part.

Galvanized Burr.

This plant is unique in that it is the only native species that has become a noxious weed. On the red soils of southern Queensland—especially in the Maranoa and on the north-western slopes in New South Wales—the weed is a serious one. It is a native of the areas infested,

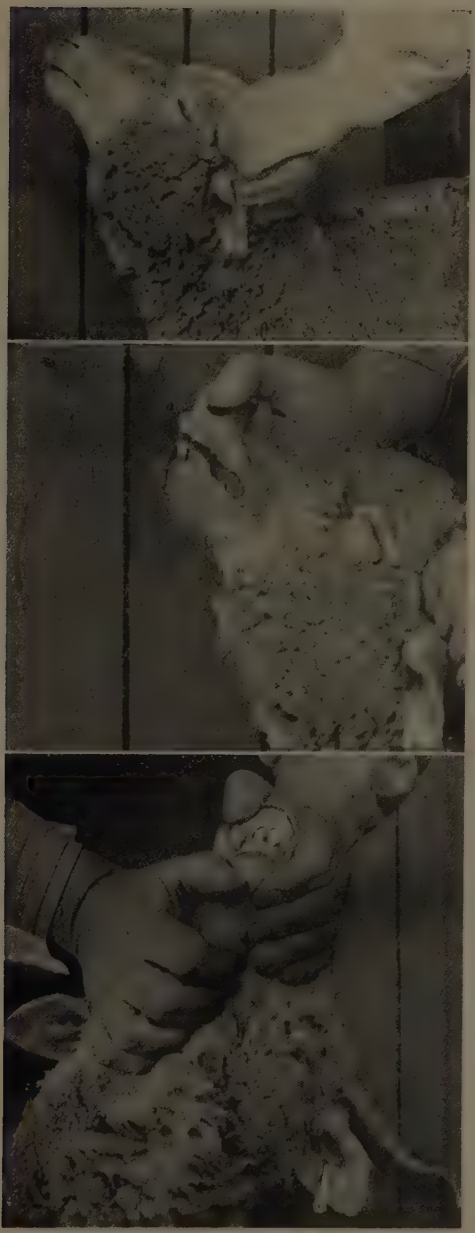
and the serious infestations are found in areas with from 18 inches to 27 inches of rain per annum. Generally speaking these areas are extensive sheep runs carrying from a sheep to 4 acres to a sheep to 2 acres. It has been suspected that overstocking with sheep has been the cause of the plant becoming a pest. An experiment laid down on Warrie Station near St. George five years ago has not, however, given any positive evidence that this is so, though it was designed to test the hypothesis. Light and heavy stocking at the respective rates of one sheep to 5 acres and one sheep to 2 acres are still equally heavily infested with the weed. There has been a very substantial increase in the density of the desirable grasses and herbages on the whole experiment as compared with the adjacent station paddocks.

In conclusion, a word may be said about chemical weedicides. After six years of tests, in only one instance have we obtained the slightest beneficial results from the application of weedicides on a fairly wide range of weeds, including hoary cress, skeleton weed, blackberry, cape tulip, nut grass, St. John's wort, bracken fern, galvanized burr, and mintweed. Perennial weeds are generally killed to ground level or slightly below, but regenerate quite vigorously, and the only annual weed among them, viz., mintweed, seeds so freely that even though we destroyed three crops in one season the density of the stand in the following season was scarcely impaired. The only exception is Phragmites—the common water reed. In this instance partial success has been obtained with dilute solutions of sodium chlorate, and in the special circumstances obtaining, the weed infests narrow water channels, effective cleaning of the channels is possible by spraying once or twice a year.

On the botanical side, therefore, the majority of the weeds present on agricultural and grazing land can only be controlled by finding plants capable of competing successfully with the weeds. In many instances this would involve radical changes of existing farming practice—as for example, in the case of hoary cress and skeleton weed.

PLATE 1.

(See p. 189.)



A sheep with short lower jaw or parrot mouth.

PLATE 2.

(See p. 213.)

FIG. 1 (above).—Young maize plant with stem apex and uppermost leaves killed by top rot.

FIG. 2 (below).—Longitudinal section of the apex of a plant similar to that shown in Fig. 1.

PLATE 3.

(See p. 213.)

Three plants inoculated before tasselling with top rot bacteria. Normal plants in background.

PLATE 4.

(See p. 213.)

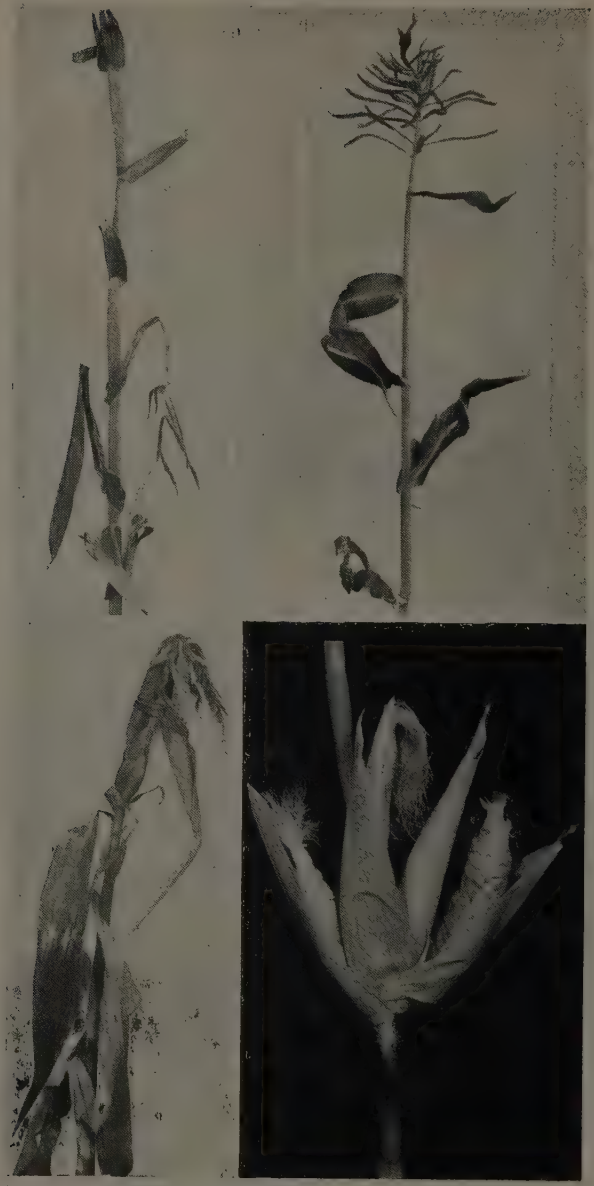


FIG. 1 (above, left).—Tassel destroyed and leaves partially destroyed by late infection of the stem apex.

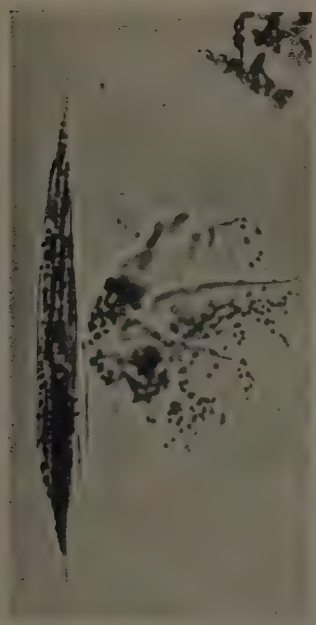
FIG. 2 (above, right).—Crumpling of tassel and leaves, following late infection of the stem apex.

FIG. 3 (below, left).—Failure of the tassel to free itself from the upper leaves, and injury to the leaves, following late infection of the stem apex.

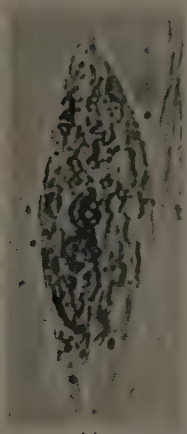
FIG. 4 (below, right).—"Multiple nubbin" ear of maize.

PLATE 5.

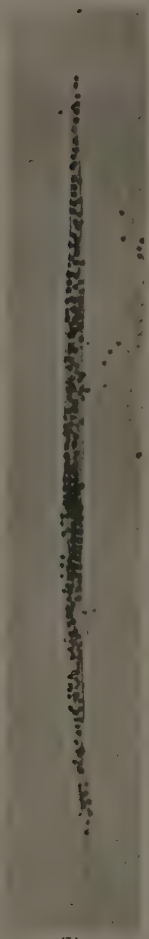
(See p. 221.)



(*a*)



(*c*)



(*b*)

a. (upper left).—Pigmented cortical cell of normal length. Note the linear arrangement of pigment granules. A fragment of the fibre cuticle is also present. × 865.

b. (right).—Pigmented cortical cell isolated from fibre stretched and set at 80 per cent longer than original length. The extension within the cell may be judged from the spacing of the granules. × 865.

c. (lower left).—Pigmented cells supercontracted with sodium sulphide solution. Note that although the external shape appears to have contracted smoothly, much internal disturbance has occured. Previously parallel rows of granules now often make definite angles with each other. The bifurcated end of the cell may still be seen. × 865.

PLATE 6.

(See p. 221.)

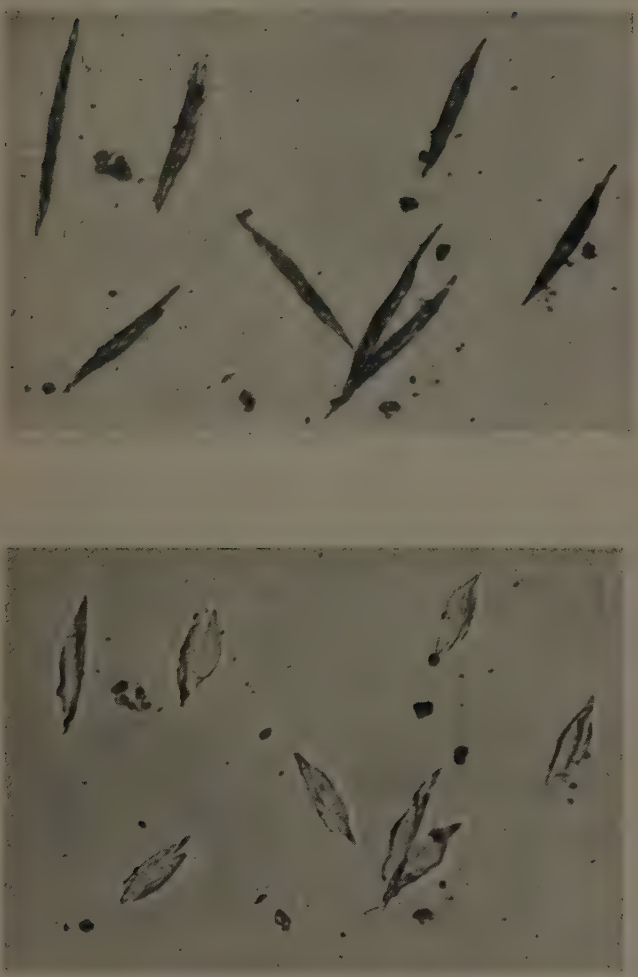
FIG. 1 (top).—Cortical cells from fine Merino wool. × 465. The forked end shown by some cells is characteristic of Merino wool.

FIG. 2 (centre).—Portion of pigmented fibre. Note the rows of pigment granules within the cortical cells. × 1115.

FIG. 3 (bottom).—Central portion of a cortical cell showing network structure. The cell was brominated, etched by sodium carbonate solution, and lightly stained with methyl violet. The cell has contracted about 10 per cent. × 1670.

PLATE 7.

(See p. 221.)



Illustrating supercontraction of isolated cells.

FIG. 1 (above).—Group of cells fastened to slide with albumen adhesive and photographed in air. × 300.

FIG. 2 (below).—Same cells after 90 seconds in alcoholic caustic potash. Photographed under the treatment liquor. × 300.

PLATE 8.

(See p. 221.)

Longitudinal section of hair follicle from guinea pig skin. The elongation of the cells within the cortex and the extrusion of the nucleus as the cells pass upwards through the prekeratinous zone AB can be seen. Keratinization within the cortex can be detected above C where the inner root sheath parts from the fibre The fibre diameter decreases above C and the cortex stains with picric acid and does not give a positive nitro-prusside test. × 300.

NOTES.

Breaking the Dormancy of Potatoes.

The Division of Plant Industry has been working for some time with methods to break the dormancy of recently dug potatoes. Most of the successful methods which have been discovered in U.S.A. for breaking dormancy involve the use of expensive chemicals, which are difficult to use and are now unobtainable. Mr. Hutton, the officer concerned, has been successful in discovering a cheap and effective method for breaking dormancy. Full technical details will be available by publication in due course, but as the breaking of dormancy may be an important problem to the potato grower due to the present shortage of potato seed, the practical outlines are made available. They are as follows:—

Half fill a container with water, and add gradually over a period of a quarter of an hour small pieces of commercial calcium carbide. The object of adding the carbide slowly is to keep the bubbles of acetylene gas passing through the water, so that it becomes saturated. Approximately 8 oz. of commercial calcium carbide, costing about 6d., will produce enough acetylene gas to saturate 11 gallons of water, which is sufficient to treat 1 cwt. of potatoes at a time. To treat 1 cwt. of seed potatoes at a time the container would have to be approximately of 16 gallons capacity. The uncut potatoes are placed in the acetylene solution and left there 4-5 hours. The potatoes must be whole at treatment because if cut just before or after treatment, the cut pieces will all rot. If the tubers do not need cutting into seed pieces they can be planted immediately after treatment provided the soil is warm and moist. When planting conditions are unsuitable, or the tubers need cutting into seed pieces, keep the tubers moist between bags in a warm place for about a week, and then plant as seed tubers or cut into seed pieces as the case may be. If the tubers are cut they should be kept in a warm moist place for 48 hours after cutting and before planting in order to obtain best results. It is admitted that the supply of calcium carbide is not as plentiful as it was before the war, but the fact remains it is cheap and easy to use. Some precautions are necessary. Calcium carbide must be kept dry in a tightly closed container otherwise it deteriorates rapidly. The acetylene gas is inflammable and so naked lights should not be allowed near the place of treatment.

The solution can be used again provided that a small quantity of carbide is added just before re-use, but it will not keep more than a couple of days.

If it is necessary to treat the seed tubers for the control of rhizoctonia it is advisable to use the acid mercuric chloride before the acetylene treatment. The treatment has the added advantage of killing any living potato moth grubs which are present.

Investigation on South American Potatoes.

In 1936, the Government of India suggested that the Empire Governments should co-operate through the Executive Council of the Imperial Agricultural Bureaux to send a botanical expedition to the Andes—the original home of the potato. The object of the expedition was to collect wild and cultivated varieties there, and to distribute them to plant breeders throughout the Empire, with the definite objective of improving existing varieties in certain specific qualities which are lacking in the common potato. The proposal was endorsed by Empire Governments and all agreed to share in the cost of this expedition. The members of the expedition set out in the latter part of 1938, and spent from January to August, 1939, in making a most comprehensive collection, consisting of over 1,400 strains and varieties of potatoes drawn from a very wide area of the Andes Mountains.

The scientific grounds for the belief that a substantial improvement in the ordinary potato could be brought about by intercrossing with wild South American types may be briefly summarized:—

(1) The domestic potato is a plant of South American origin, and was unknown in Europe before the time of the discovery of America. The first potatoes brought to Europe consisted of chance samples picked up by explorers with little or no botanical knowledge, and did not constitute an exhaustive or indeed even a representative sample of the potatoes in their native land. Moreover, there has, since that time, been little or no attempt to enlarge the range of potato material by further collections, and hence all the potato varieties in general cultivation have originated from these few early introductions. Any desirable character not yet found in the domestic potato, e.g. frost resistance, resistance to disease, resistance to drought, and tolerance of short days, is not present in the European material and therefore no amount of breeding among European types will ever produce it. This does not necessarily mean that it was not present in the potato's natural home, and the expedition was therefore sent to put the possibility to the test.

(2) The South American potato, in contrast to the uniformity familiar to us in the domestic potato, was found to consist of a multitude of different types many of them being scarcely recognizable as potatoes by a European observer. This remarkable diversity is associated with the variety of conditions under which it grows. The members of the expedition found that the potato occurred naturally from Chile in the south beyond the equator to the Tropic of Cancer in the north, and through all gradations of conditions from tropical valleys to zones of permanent snow. The extreme hardiness of potatoes of Peru and Bolivia has been commented on by most travellers, and it is clear that these native types are entirely different from the relatively tender plant now in general cultivation.

From these forms it should be possible by inter-breeding to produce hardy varieties of potatoes capable of growing in drier and hotter localities than the common European type, and moreover varieties that are much more resistant to disease and frost.

For Australia there is one factor of special significance in this material, namely, the potatoes of South America are short-day forms, and may therefore be expected to produce varieties that are more tolerant of short days than the forms we now grow.

The Executive Council of the Imperial Agricultural Bureaux has given earnest consideration to the question of making the most effective use of this potentially valuable breeding material, and to that end has sought advice from scientific organizations throughout the Empire. It has been decided to concentrate preliminary work at one centre, Cambridge, and Empire Governments have recently been asked to support the scheme.

Recent Publications of the Council.

Since the last issue of the *Journal*, the following publication of the Council has been issued:—

Bulletin No. 146.—"An Analysis of the Outbreaks of the Australian Plague Locust (*Chortoicetes terminifera* Walk.) during the Seasons 1937-38 and 1938-39," by K. H. L. Key, M.Sc., Ph.D.

This Bulletin describes some of the work being done by the Council and the State Departments of Agriculture in the control of locusts and grasshoppers.

The bulk of the damage is caused by the Australian plague locust (*Chortoicetes terminifera*), which forms large, dense swarms having a range of migration of several hundred miles under suitable conditions, and the small plague grasshopper (*Austroicetes cruciata*) which usually occurs in loose swarms only, and has a maximum range of about 15 miles. In New South Wales and Queensland, the Australian plague locust is of chief importance, and the present Bulletin discusses the outbreaks of this insect from 1937 to 1939. A study of previous outbreaks had shown that again and again the first swarms were recorded in or near one of a few, relatively small, regions situated mainly in central New South Wales. Locust Information Services were accordingly set up to obtain fuller details of outbreaks from 1937 onwards. The importance of the outbreak areas has been confirmed, and they have been mapped more accurately. It has also been found that swarms can maintain themselves only as long as temperature and rainfall remain within certain defined limits.

Rough forecasts can now be made of future outbreaks, and knowledge of the outbreak areas should enable swarms to be poisoned before they have had a chance to spread far. It has been estimated that, in New South Wales alone, losses from locusts in the 1937-38 season would have amounted to several million pounds if no control measures had been taken; great savings should therefore be effected with improved means of control.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 148.—"Studies in Fertility in Sheep. II. Seminal Changes Affecting Fertility in Rams," by R. M. C. Gunn, D.V.Sc., B.Sc.Agr., M.R.C.V.S., R. N. Sanders, B.V.Sc., and W. Granger, B.V.Sc.

Bulletin No. 149.—"Production of Dried Grapes in Murray Valley Irrigation Settlements. 2. Irrigation, Drainage, and Reclamation," by A. V. Lyon, M.Agr.Sc., and A. L. Tisdall, M.Agr.Sc.

Bulletin No. 150.—"The Soils of the Parishes of Longford, Cressy, and Lawrence, County Westmorland, Tasmania. 1. A Soil Survey of the Area. 2. Pot Experiments with Subterranean Clover on the Cressy Shaley Clay-loam," by C. G. Stephens, M.Sc., A.A.C.I., J. G. Baldwin, B.Agr.Sc., B.Sc., and J. S. Hosking,, M.Sc., A.I.C., A.A.C.I.

Bulletin No. 151.—"The Control of St. John's Wort (*Hypericum perforatum* L. var. *angustifolium* D.C.) by Competing Pasture Plants," by R. M. Moore, B.Sc.Agr., and A. B. Cashmore, M.Sc.

Bulletin No. 152.—"Soil Survey of Part of County Moira, Victoria, including the Parishes of Boosey, Cobram, Katamatite, Naringaninga-look, Katunga, Yarroweyah, and Strathmerton," by B. E. Butler, B.Sc.Agr., J. G. Baldwin, B.Agr.Sc., B.Sc., F. Penman, M.Sc., and R. G. Downes, M.Agr.Sc.

Bulletin No. 153.—"Pelagic Tunicates in the Plankton of South-eastern Australian Waters, and their Place in Oceanographic Studies," by H. Thompson, M.A., D.Sc., with a Statistical Analysis of Data on Total Plankton, by G. L. Kesteven, B.Sc.

Bulletin No. .—"Standardized Plant Names. A List of Standard Common Names for the more Important Australian Grasses, other Pasture Plants, and Weeds," prepared by the Division of Plant Industry.

Bulletin No. .—"The Handling and Storage of Australian Oranges, Mandarins, and Grapefruit." Report of Investigations carried out under the direction of the Citrus Preservation Technical Committee from 1935 to 1941, and compiled by F. E. Huelin, B.Sc., Ph.D.

Bulletin No. .—"Studies in the Biology of Australian Mullet. 1.—Account of the Fishery and Preliminary Statement of the Biology of *Mugil dobula* Gunther," by G. L. Kesteven, B.Sc.

Bulletin No. .—"The Lubricating Effect of Thin Metallic Films and the Theory of the Action of Bearing Metals," by F. P. Bowden, Sc.D. (Cantab.), and D. Tabor, Ph.D. (Cantab.), A.R.C.S.

Pamphlet No. 113.—"Drainage Investigations in the Horticultural Soils of the Murray Valley," by A. L. Tisdall, M.Agr.Sc.

Pamphlet No. 114.—"Plant Introduction. 1. A Review, with Notes on Outstanding Species," by A. McTaggart, Ph.D. "2. Preliminary Selection and Evaluation of Pasture Species at Lawes (Queensland)," by T. B. Paltridge, B.Sc.

Pamphlet No. 115.—"Studies on the Shrink-proofing of Wool. 1. The Industrial Development of the Freney-Lipson Process at Hole-proof Limited, Melbourne. 2. Further Studies on the Prevention of Shrinkage in Woollen Goods," by M. Lipson, B.Sc., A.A.C.I., and Carmel J. Clyne, B.Sc. "3. Experimental Work on the Treatment of Wool by the Woolindras Process," by D. R. Zeidler, M.Sc.

Industrial Chemistry Circular No. 1.—"Some Technical Aspects of Foundry Cores," by H. A. Stephens, B.Sc.

"Termites (Isoptera) from the Australian Region (including Australia, New Guinea, and Islands South of the Equator between 140 deg. E. Longitude and 170 deg. W. Longitude)," by Gerald F. Hill.

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